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RESEARCH AND DEVELOPMENT TECHNICAL REPORT

ECOM-0058-F

SATELLITE AND RADAR ANALYSIS OF MESOSCALE WEATHER SYSTEMS

FINAL REPORT

By

HAROLD P. GERRISH

July 1976

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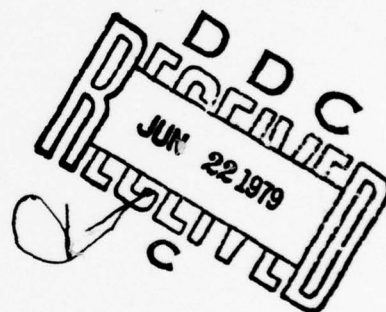
FOR

Atmospheric Sciences Laboratory
U.S. Army Electronics Command
White Sands Missile Range, N.M. 88002

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Relationships between satellite visible and I.R. gray levels, and such parameters as the existence of radar echoes, ceiling height and surface visibility are studied using SMS-1/GOES satellite data, digital radar data, surface observations from first order stations, and the Kennedy Space Center Image 100 Multispectral Image Analyzer. Radar echo/rainfall relationships are also studied using rain gauge data from the 1975 FACE mesonetwork.

The results from four case studies during August 1975 show that radar

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CONT

echoes occurred, without exception, when both types of satellite gray levels exceeded a value of 183 based on a scale of 0 (black) to 255 (white). Other joint relationships are described for lower gray levels. It is shown that the lowest ceilings and surface visibilities occurred with the satellite visible levels near 100 and the I.R. levels near 130 and 110 respectively. An example is presented showing the simulation of a radar echo pattern from themed satellite visible data on 14 August 1975. And computer programs are appended for converting 7-track NHEML KART digital radar tapes to 9-track tapes with suitable block size and format for the KSC PDP 11/35 computer system.

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SECTION 1 - OVERVIEW

1.1. INTRODUCTION

In tropical latitudes where the clouds are predominantly of
convective origin, it is reasonable to expect that generally the more
intense radar echoes and thus the greater rainfall rates would be
associated with the taller, brighter (colder) clouds. Indeed, the
work of Griffith et al. (1973 and 1976) heavily supports such a con-
tention. Moreover, the ceiling heights and surface visibilities would
tend to be lower with the more intense convection. These generalities
strongly suggest that specific relationships can be found to permit the
identification of such meteorological parameters direct from satellite
imagery. Further, the ability to depict radar patterns and intensi-
ties from satellite data would make it possible to determine the loca-
tion of turbulence, gusty winds, hail and tornado activity, and other
parameters. This overall capability would be of obvious importance to
the U.S. Army. Accordingly, the purpose of this work was to investigate
basic relationships between satellite gray levels and the existence of
radar echoes, ceiling height, and surface visibility in South Florida
with the ultimate goal of developing identification techniques. Radar
echo/rain relationships were also examined.

A rather impressive collection of input data were used in the
analysis. SMS-1/GOES satellite visible and I.R. transparencies were
provided by the Satellite Field Services Station in Miami. Digital

WSR-57 radar data together with special rain gauge and radiosonde data were provided by the National Hurricane and Experimental Meteorology Laboratory. The National Climatic Center provided the surface weather observations which contained ceiling heights and surface visibilities for first order stations. The analysis was performed on the highly sophisticated Kennedy Space Center Image 100 Multispectral Image Analyzer through an arrangement between the Atmospheric Science Laboratory, White Sands Missile Range, the Kennedy Space Center (KSC) Data Analysis Facility, and the University of Miami.

The analytical procedure was to contour the satellite visible, I.R., and radar data into various gray or intensity levels (themes) and then make comparisons of the specific values at grid points within the special mesonetwork of rain gauges installed for the 1975 FACE experiment in South Florida. The satellite/ceiling height and surface visibility comparisons were made for the Fort Myers, West Palm Beach, and Ft. Lauderdale airports. Case studies were analyzed for 13, 14, 18, and 21 August 1975.

1.2 SUMMARY OF RESULTS

This brief study has shown that specific relationships do exist between satellite visible and I.R. gray levels, and such parameters as the existence of radar echoes, ceiling height, and surface visibility. Echoes were found to occur, without exception, when the satellite visible and I.R. gray levels exceeded a value of 183, based on a scale of 0 (black) to 255 (white). Most of the echoes occurred, however, with satellite visible gray levels of 131-216 and I.R. levels

of 163-192; and visible levels of 131-147 and I.R. levels of 193-222.

A good correlation was shown between radar echo and rain patterns over the rain gauge mesonetwork but the linear correlation coefficients between the intensities were surprisingly low. The reason for that was not clear; perhaps it was related to registration errors.

It was interesting to note that this study revealed clear relationships between satellite gray level and ceiling height as well as surface visibility. The lowest ceilings occurred when the visible gray level was near 100 and the I.R. level was near 130. The lowest surface visibilities occurred with the same visible gray levels but with the I.R. level near 110 instead of 130. Those observations appeared to be consistent with our understanding of tropical cumulus development.

An example was presented showing how a radar echo pattern could be simulated from themed satellite visible data on 14 August 1975. The reproduction was quite good and suggestive that further work should be performed in this area.

Finally, a series of computer programs was developed to convert the 7-track NHEML KART digital radar tapes to 9-track tapes with suitable block size and format for input into the KSC PDP 11/35 computer system.

1.3   CONCLUSIONS AND RECOMMENDATIONS

This study has produced a series of findings that support our initial contentions and thus the stage is set for additional work in meteorological parameter depiction from satellite imagery. From the

operational standpoint it would be quite handy to be able to push a button and produce a complete, simulated, radar display from satellite imagery. Therefore, not only should more work be performed on pattern relationships, but the effort should be large enough to investigate intensity relationships as well. The findings with respect to ceiling heights and surface visibilities are suggestive that satellite imagery potentially contains a wealth of meteorological information.

The Image 100 system is ideally suited for the sophistication that is needed in this type of work. Of the many sources of possible errors, it is essential that registration errors be held to a minimum. The electronic stacking capabilities of the Image 100 system provide unparalleled accuracy in registration. Moreover, the system has a *multispectral capability that received only* cursory use in this study because of analytical time restraints. Future work should utilize that capability.

It is recommended that film gamma be normalized in future studies and that taped satellite products be used as available. Other procedures should be standardized such as using the same aperture setting of the lens, the same gray level range of themes, etc. For this initial study such rigor was not required.

SECTION 2 - DETAILED DESCRIPTION OF WORK

2.1 INPUT DATA

SMS-1/GOES visible and I.R. transparencies served as the satellite input data for this study. Operational products were used and no effort was made to normalize the densities for differences in film gamma. The visible resolution was ½ mile for the 13 and 14 August cases, 2 miles for the 18 August case, and 1 mile for the 21 August case. The I.R. resolution was 4 miles for all cases. Efforts were made to try to use SMS-1 and SMS-2 data as stereo pairs but the attempt was abandoned as being beyond the scope of this study which was limited to only 4 meteorologist man months.

Digital WSR-57 radar data which had been rectified into 1 n. mile by 1 n. mile grid squares using the NHEML KART program, were provided to us on 7-track tape and in printout form. One printout covered the entire area shown in Figure 1. In order to analyze the digital data at the KSC, it was necessary for us to develop a series of computer programs to convert the 7-track KART tapes into 9-track tapes with suitable block size and format for input into the KSC PDP 11/35 computer system. This turned out to be a sizable task and thus it represented a major contribution to the research effort. Those programs are appended to this report. The radar data on the printouts were coded as shown in Table 1.

Fifteen-minute rainfall data from the 1975 FACE rain gauge network were used in this study. This network was located south of

Lake Okeechobee, see Figure 1, and contained 66 tipping bucket rain gauges, see Figure 2. The rainfall rates in inches/15 minutes were converted to mm/hr for comparison with the radar data.

Official NWS surface weather observations served as the basis for the ceiling height and surface visibility input data. The record observations were taken approximately 5 minutes before the hour but special observations were taken as necessary.

2.2   SELECTION OF CASE STUDIES

After reviewing the availability and quality of the input data, the four cases as shown in Table 2 were selected for specific study. It was felt that the rainfall data slightly later than the radar data would produce more realistic correlations. Even though the time departures of the ceiling height and surface visibility data ranged between 5 and 25 minutes from the other data, the values were considered to be reasonably reliable in light of the earlier or later surface observations.

The daily rainfall patterns for the case dates are shown in Figures 3-6. The rainfall on 13 August occurred mostly near Miami and just southwest of Lake Okeechobee. On the 14th the rainfall occurred mostly over the center of the peninsula. The rainfall was predominately just inland from the east and southwest coasts on the 18th. And the rainfall was near the west coast on the 21st. These were considered to be representative patterns for the South Florida area.

The 2100Z radiosonde soundings taken at the 1975 FACE Field Observation Site are shown in Figures 7-10. The sounding on 13 August
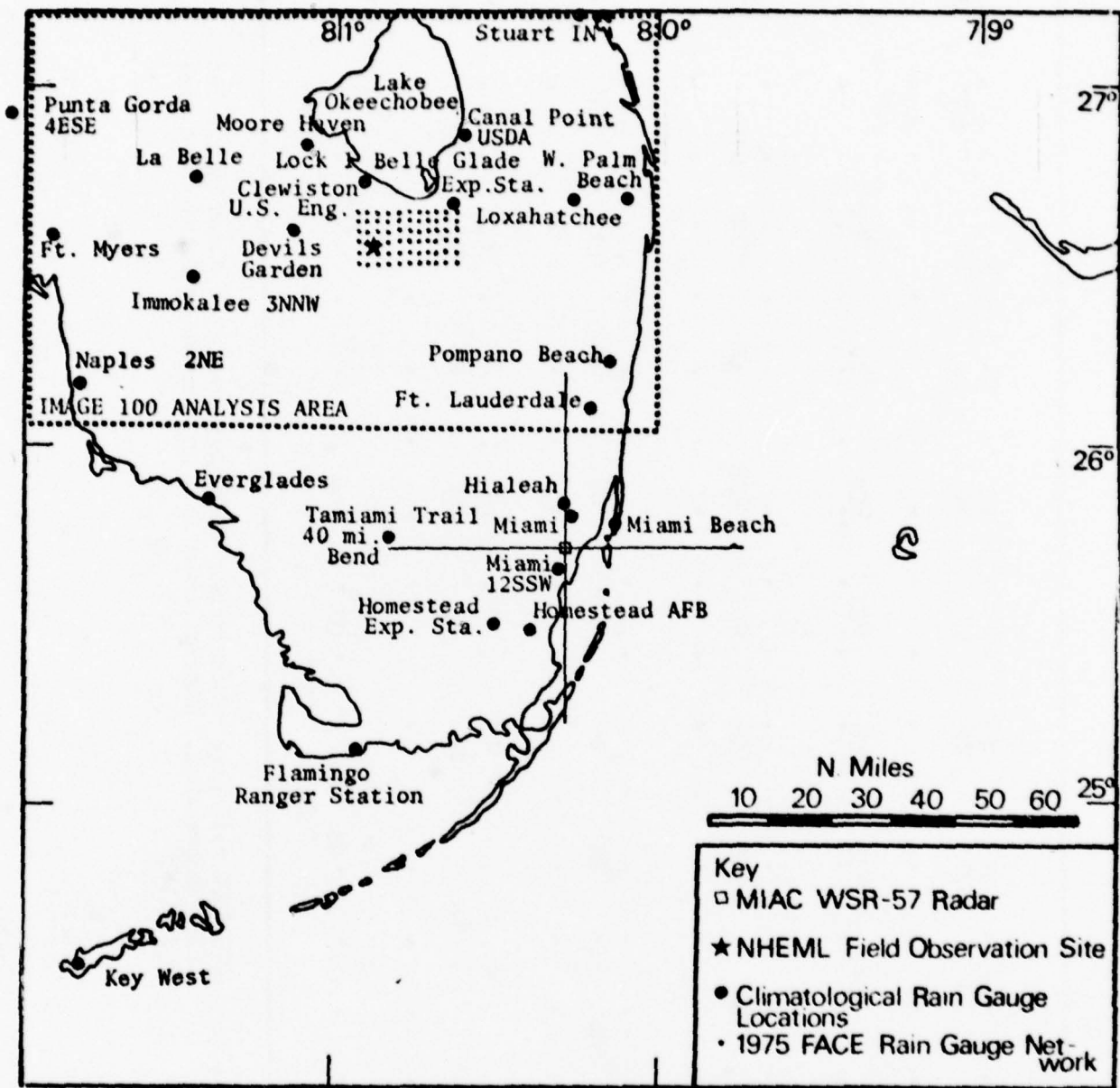
FIG. 1 - Map of digital radar coverage area.

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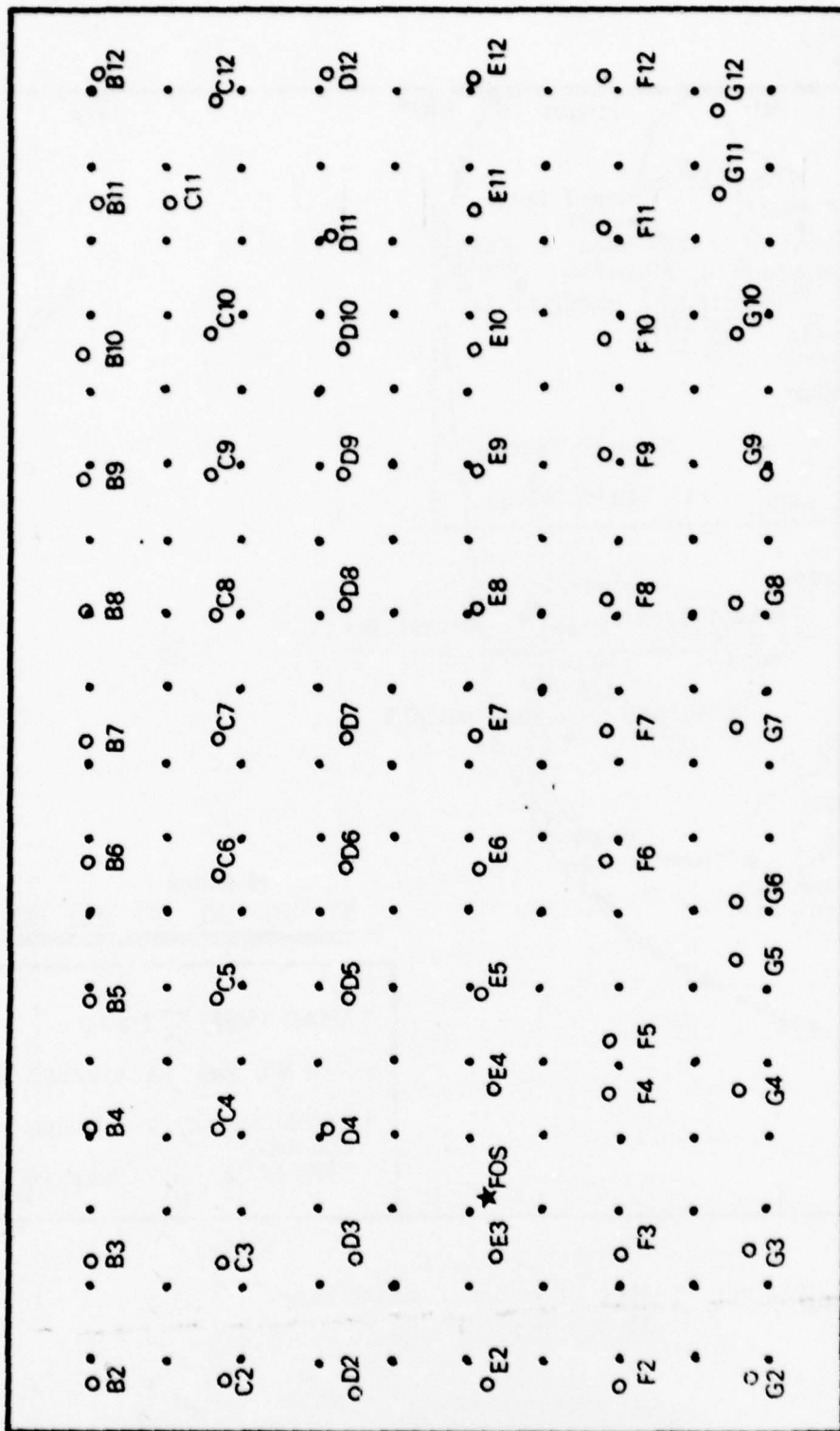
FIG. 2 - 1975 FACE rain gage mesonetwork. Rain gage locations shown by circles labled B through G. Digital radar data grid shown by dots---mesh size 1 n. mile.

PRINTOUT CODE	2130Z 13 AUG 75	1930Z 14 AUG 75	1915Z 18 AUG 75	2110Z 21 AUG 75
.	3.08 - 6.16	1.63 - 3.27	1.66 - 3.33	2.37 - 4.75
1	6.16 - 12.31	3.27 - 6.53	3.33 - 6.66	4.76 - 9.50
2	12.31 - 18.47	6.53 - 9.80	6.66 - 9.98	9.50 - 14.24
3	18.47 - 24.62	9.80 - 13.07	9.98 - 13.31	14.24 - 18.99
4	24.62 - 30.78	13.07 - 16.34	13.31 - 16.64	18.99 - 23.74
5	30.78 - 36.93	16.34 - 19.60	16.64 - 19.97	23.74 - 28.49
6	36.93 - 43.09	19.60 - 22.87	19.97 - 23.30	28.49 - 33.24
7	43.09 - 49.24	22.87 - 26.14	23.30 - 26.62	33.24 - 37.98
8	49.24 - 55.40	26.14 - 29.40	26.62 - 29.95	37.98 - 42.73
9	55.40 - 61.55	29.40 - 32.67	29.95 - 33.28	42.73 - 47.48

TABLE 1 - Digital radar printout code. Rainfall rates are in mm/hr.

	CASE DATES			
	13 AUG 75	14 AUG 75	18 AUG 75	21 AUG 75
Satellite Visibile	2130	1930	1930	2100
Satellite I.R.	2130	1930	1900	2100
Radar	2130	1930	1915	2110
Rainfall	2130 - 2145	1930 - 1945	1915 - 1930	2115 - 2130
Ceiling Height	2155	1955	1855	2055
Surface Visibility	2155	1955	1855	2055

TABLE 2 - Times (Z) of the various data used in the case studies.
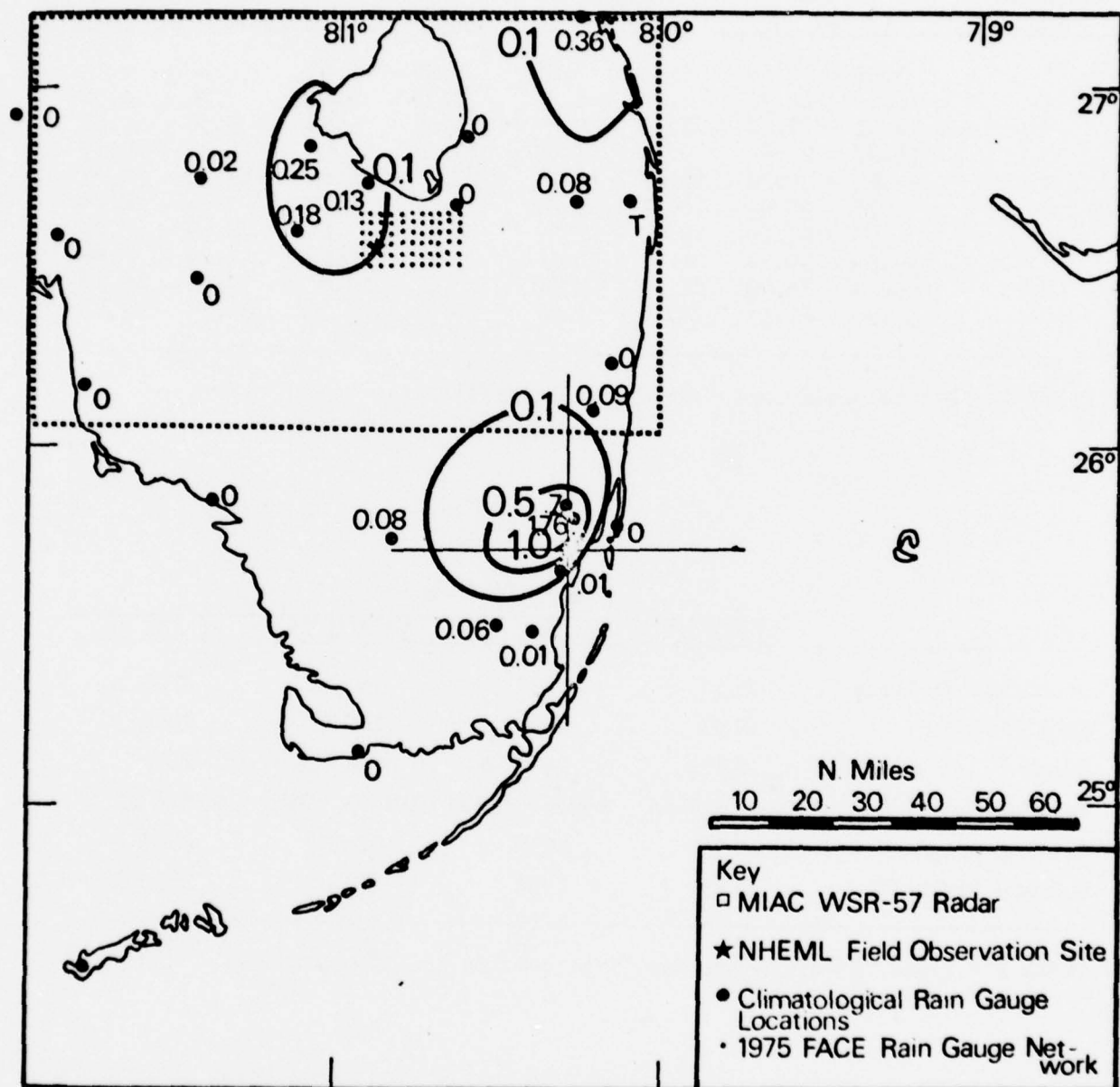
FIG. 3 - Daily rainfall pattern, 13 August 1975. Isohyets in inches.
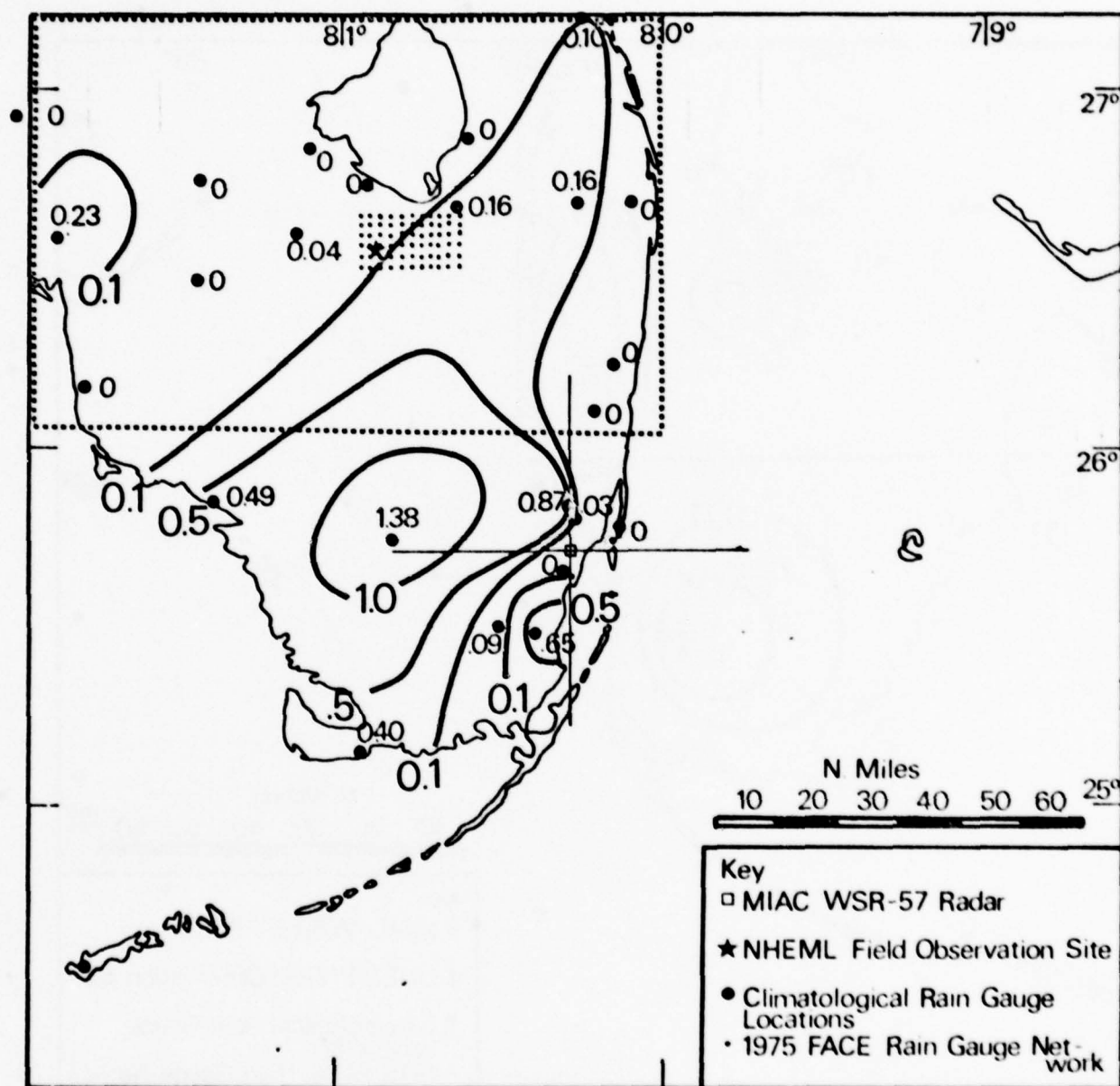
FIG. 4 - Daily rainfall pattern, 14 August 1975. Isohyets in inches.

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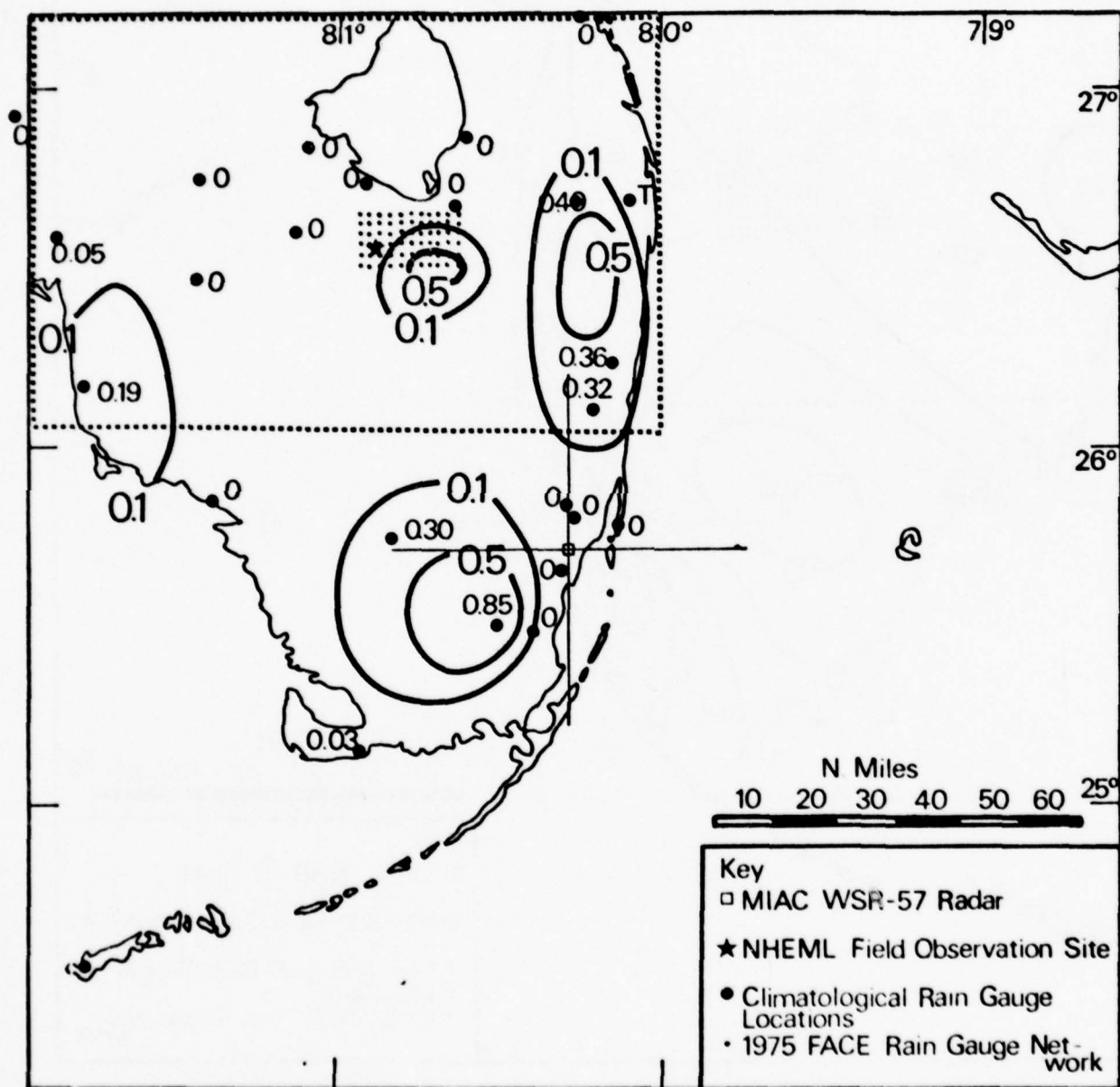
FIG. 5 - Daily rainfall pattern, 18 August 1975. Isohyets in inches.
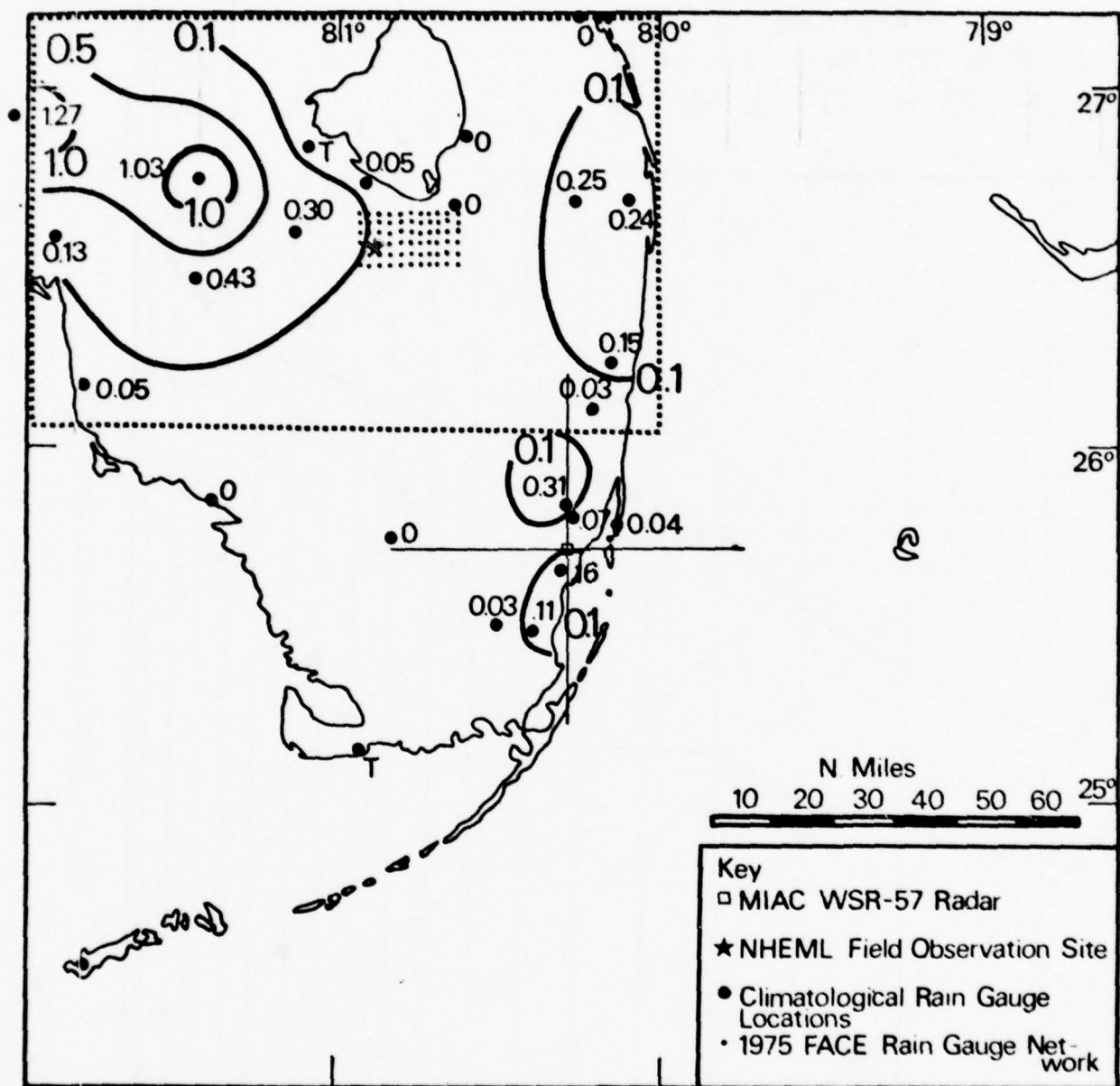
FIG. 6 - Daily rainfall pattern, 21 August 1975. Isohyets in inches.

14

SKEW T, LOG P DIAGRAM
NHEML Field Observation Site
2100 Z Sounding
13 August 1975

FIG. 7 - 2100Z sounding, 13 August 1975.
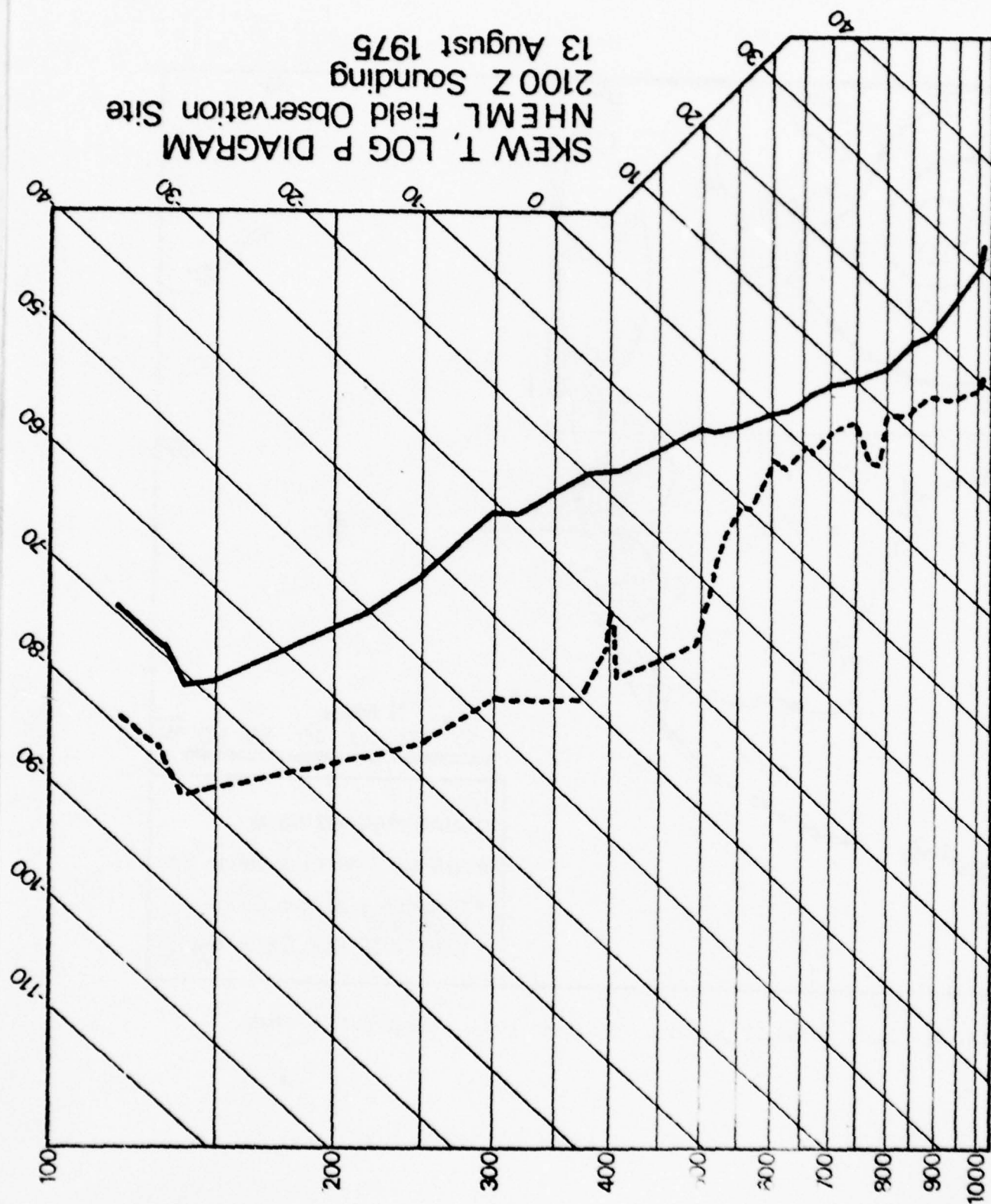
SKEW T, LOG P DIAGRAM
NHEML Field Observation Site
2100 Z Sounding
14 August 1975

FIG. 8 - 2100Z sounding, 14 August 1975.
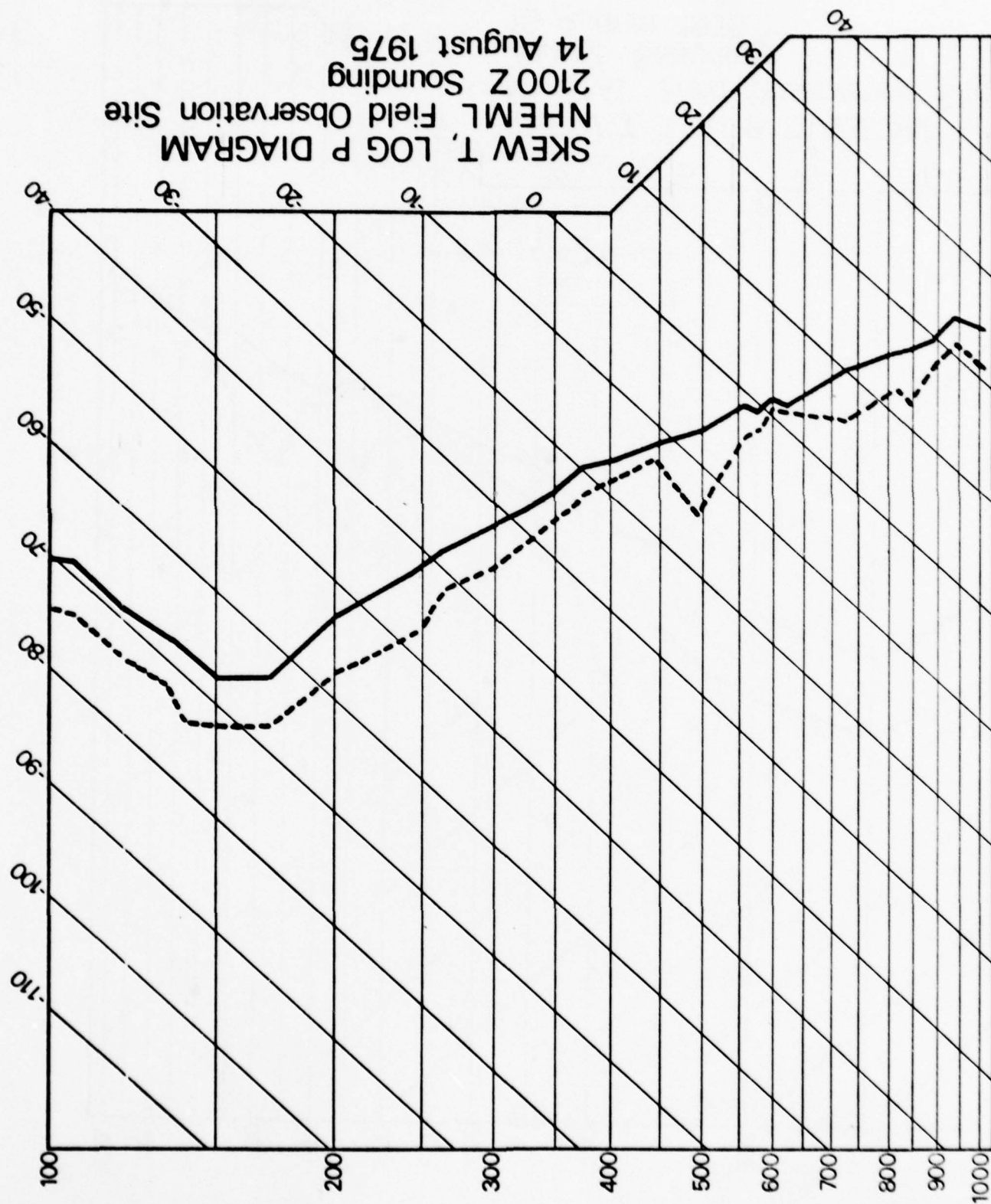
SKEW T, LOG P DIAGRAM
NHEML Field Observation Site
2100 Z Sounding
18 August 1975

FIG. 9 - 2100Z sounding, 18 August 1975.
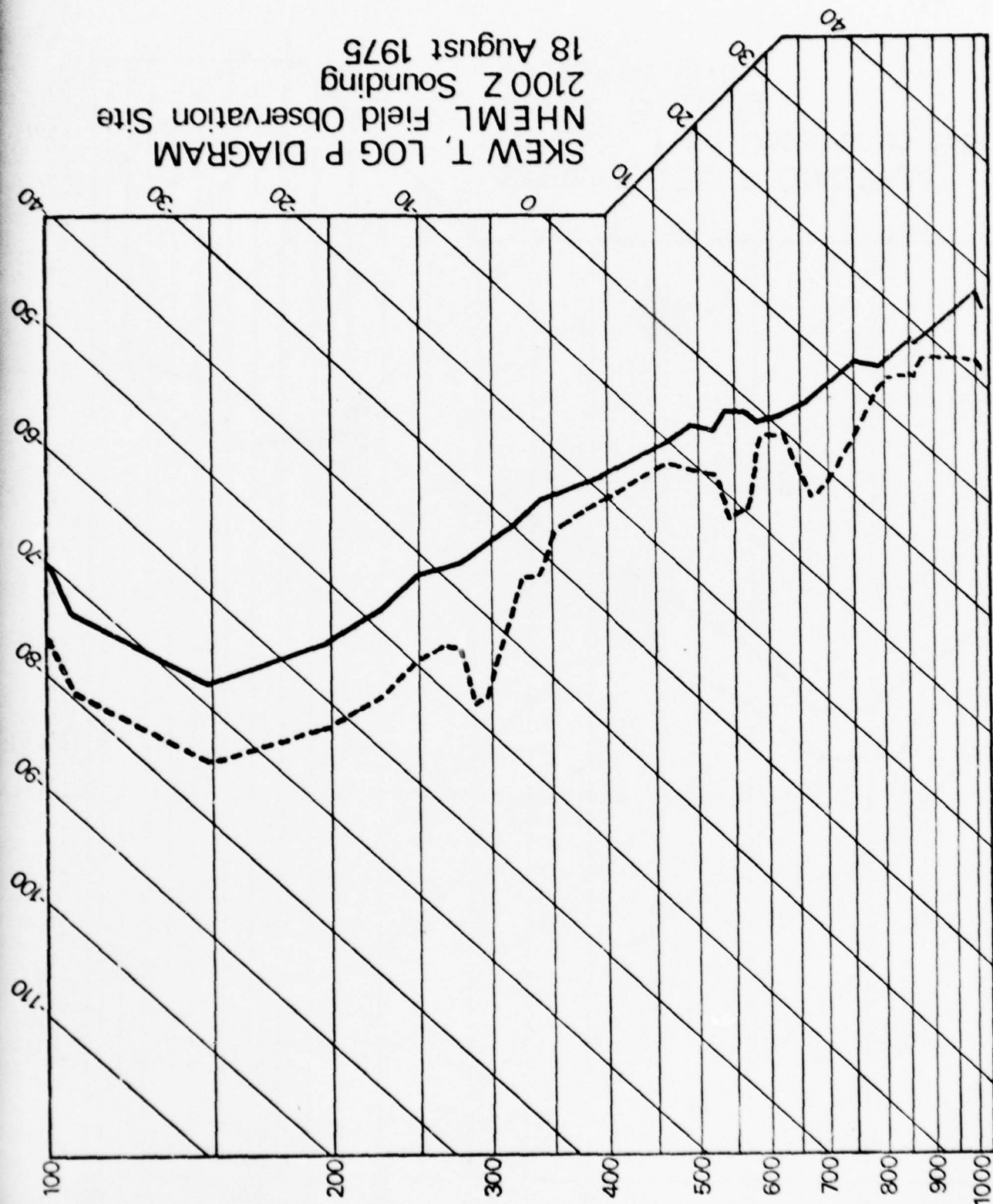
SKEW T, LOG P DIAGRAM
NHEML Field Observation Site
2100 Z Sounding
21 August 1975
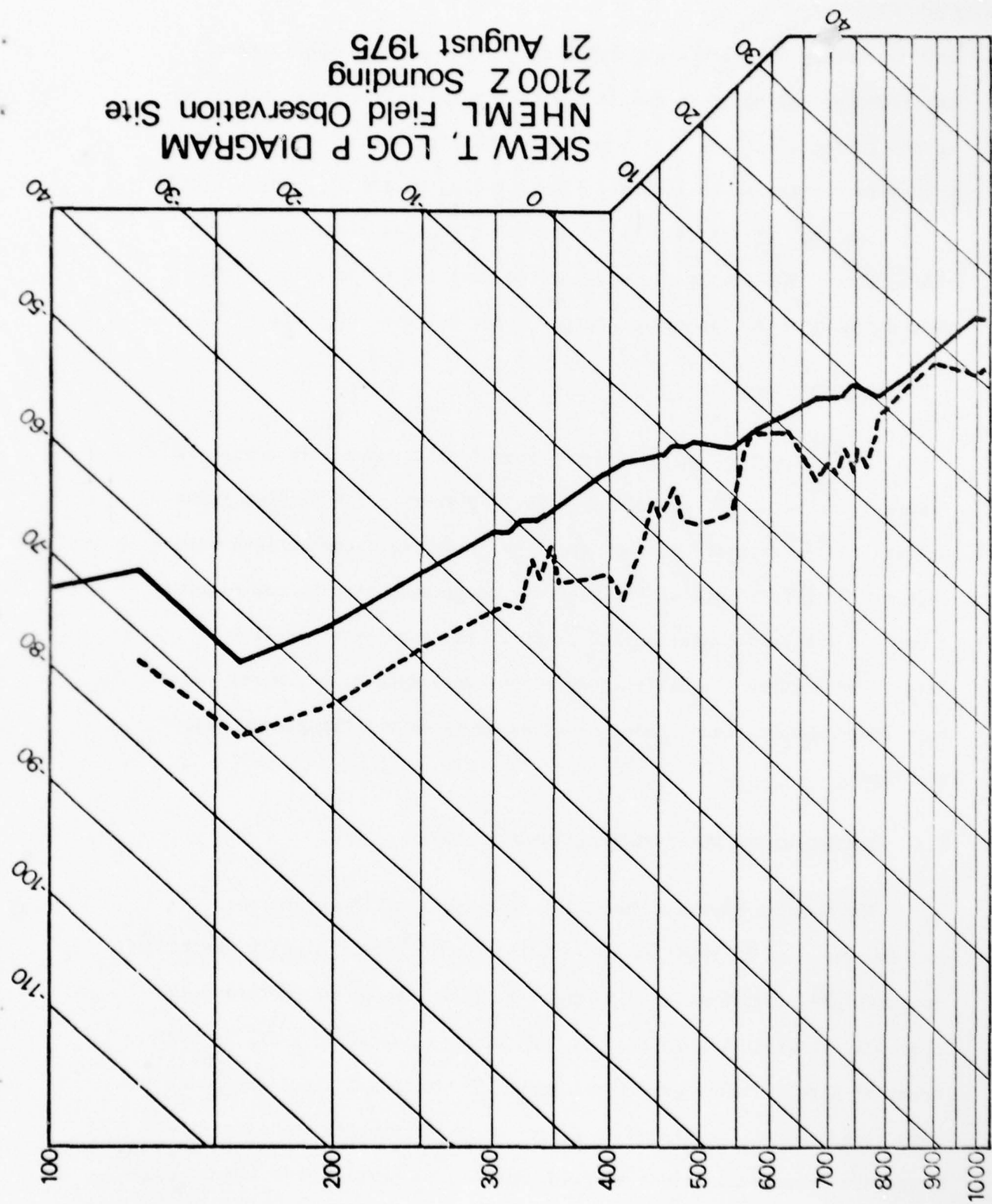
FIG. 10 - 2100Z sounding, 21 August 1975.

was relatively dry with a superadiabatic lapse rate at the surface. The sounding was moist on the 14th with a relatively deep stable layer at the surface. It was not as moist on the 18th and an inversion at the surface extended to 1000 mb. The sounding on the 21st was slightly drier than that on the 18th and contained a shallow stable layer at the surface. The tropopause was located near 150 mb on each of the case dates with the tropopause temperatures between -65°C and -71°C.

2.3   ANALYSIS AREA

The "Image 100 Analysis Area" shown in the upper left corner of Figure 1 served as the general area for registering the various forms of data. Once registered, the satellite, radar/rain comparisons were made at the grid points within the rain gauge mesonetwork, see Figures 1 and 2. The grid contained 180 points. The satellite, ceiling height and surface visibility comparisons were made at Ft. Myers, West Palm Beach and Ft. Lauderdale, near the edges of the "Image 100 Analysis Area".

2.4   THE IMAGE 100 MULTISPECTRAL IMAGE ANALYZER

The General Electric Image 100 Multispectral Image Analyzer at the KSC was used to register the satellite data electronically and to document gray levels at grid points. A block diagram of the Image 100 system is shown in Figure 11. The CRT display contained a 512 by 512 array of pixels with a gray level range of 0 to 255. Since the radar data were contrast stretched to assist with registering the satellite data, the radar comparisons at grid points were performed by hand
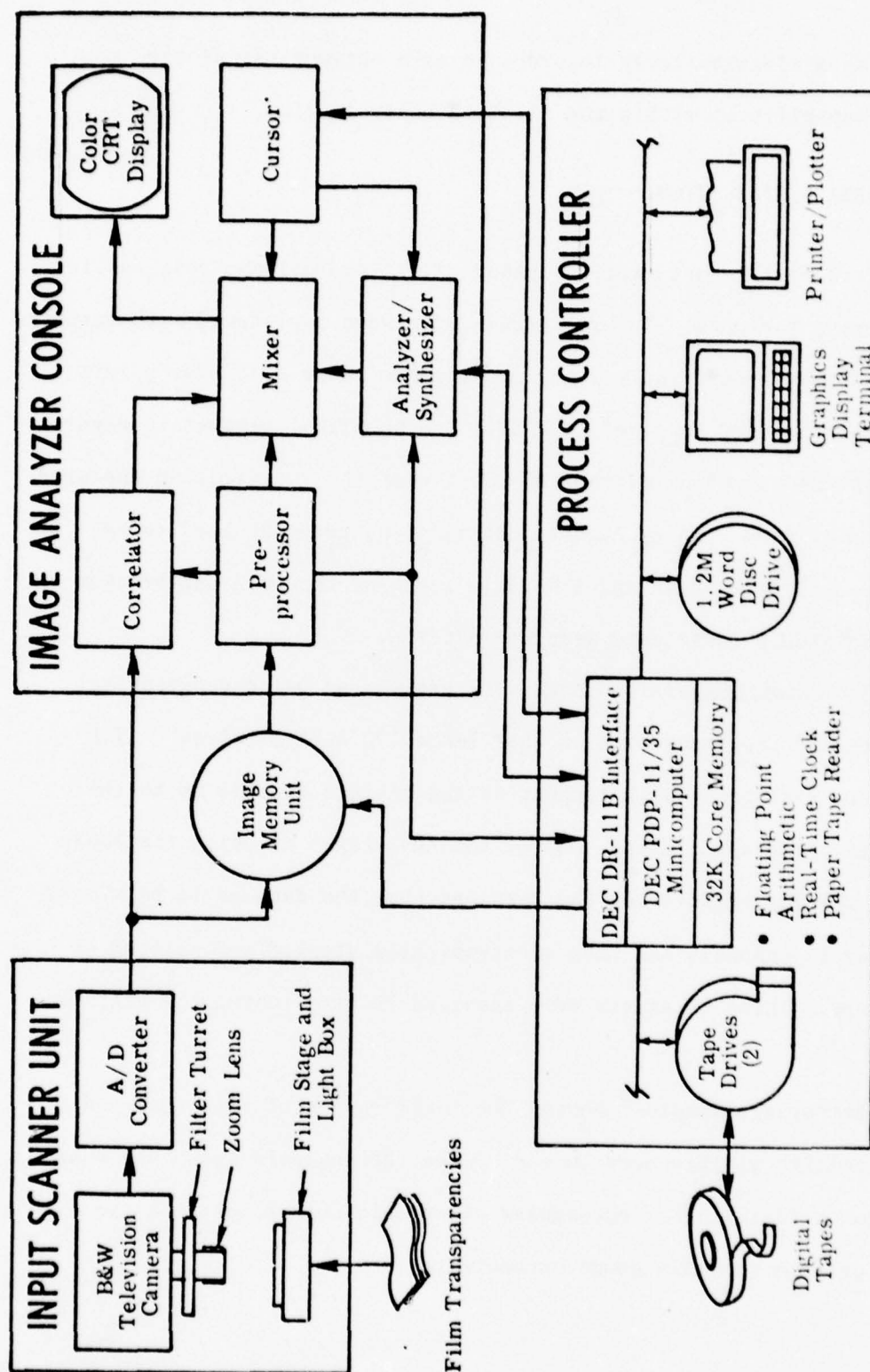
FIG. 11 - Image 100 system block diagram.

rather than electronically in order to make optimum use of the system capabilities within the allotted analysis time.

2.5 DATA REGISTRATION

Perhaps the most critical phase of the overall analysis was in registering the data. The radar/rain data were registered with respect to each other by carefully superimposing the radar grid over a rain gauge location map supplied by NHEML, see the final product in Figure 2. With the exception of the 18 August case, the registration appeared to be quite good. On 18 August, the radar pattern appeared to be shifted 3 n. miles west and 1 n. mile south of the rain pattern but for consistency those data were not altered.

The satellite visible data were registered using geographical features and the radar data in the "Image 100 Analysis Area". I.R. data were registered with respect to the visible as well as to the radar and geographic data. One of the advantages of using the Image 100 system for registering the data was that the data could be stored in separate channels and then electronically stacked and shifted as necessary. Three observers were involved in fine tuning the registration.

Pictorial examples showing the registration of the radar and the satellite visible data in the "Image 100 Analysis Area" are shown in Figures 12-15. The rectangular electronic cursor outlines the radar grid in the rain gauge mesonetwork.

FIG. 12 - Radar echoes superimposed over satellite visible data in Image 100 analysis area, 13 August 1975 case. Rectangular cursor outlines rain gauge mesonetwork.
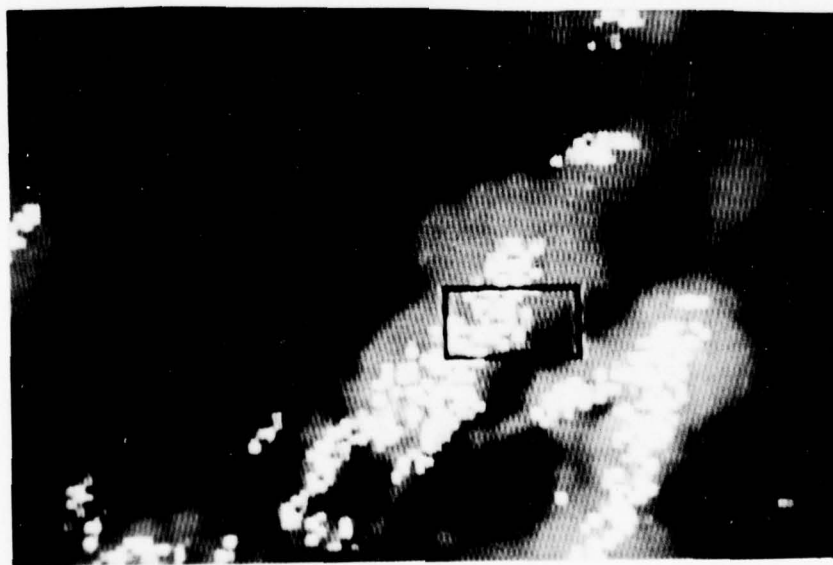
FIG. 13 - Radar echoes superimposed over satellite visible data in Image 100 analysis area, 14 August 1975 case. Rectangular cursor outlines rain gauge mesonetwork.

FIG. 14 - Radar echoes superimposed over satellite visible data in
         Image 100 analysis area, 18 August 1975 case. Rectangular
         cursor outlines rain gauge mesonetwork.
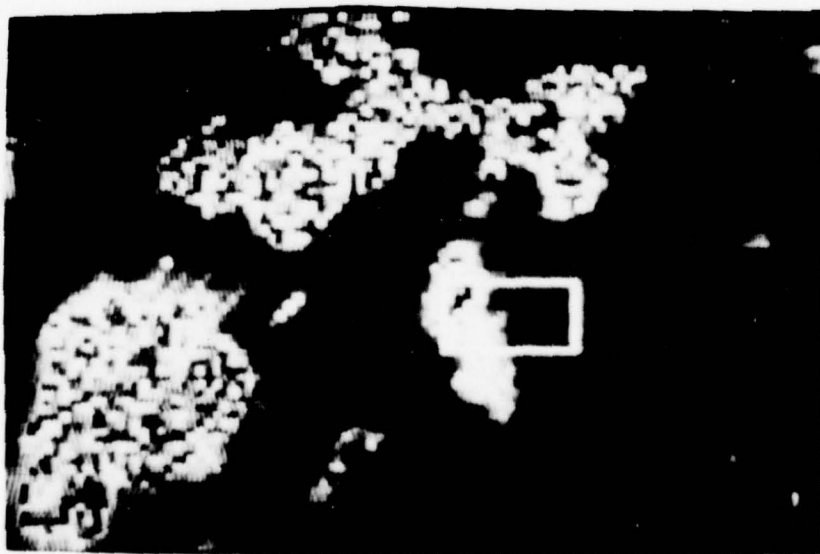
FIG. 15 - Radar echoes superimposed over satellite visible data in
         Image 100 analysis area, 21 August 1975 case. Rectangular
         cursor outlines rain gauge mesonetwork.

2.6   ANALYSIS PROCEDURE

Numerical values of the satellite visible and I.R. gray level density themes for each pixel within the mesonetwork grid, see Figure 2, were tabulated using the Image 100 Printer/Plotter. Values for the 180 grid points were then manually taken from that array. Values of the contrast stretched radar data were also tabulated but not used in the grid point analysis. Instead, the unmodified data from the digital radar printouts were used (recall that those data were already gridded into a 1 n. mile mesh).

For the radar/rain correlations, the rain data were plotted on maps like that in Figure 2 and then the values at the grid points were extrapolated from the isohyetal analysis.

The procedure for the satellite/ceiling height, surface visibility comparisons was to tabulate the average satellite gray level for the four pixels immediately surrounding the Ft. Myers, West Palm Beach, and Ft. Lauderdale airports. The average values were then compared with the observed ceiling heights and surface visibilities.

2.7   SATELLITE/RADAR ECHO RELATIONSHIPS

Figures 16-19 summarize the joint relationship between satellite visible and I.R. gray levels, and the existence of radar echoes at the 180 grid points. Eight themes or class intervals of density ranges were used for each case. The numerical values for each theme varied from case to case because of differences in the dynamic range of the observed gray levels. Unique relationships would be indicated when the contoured echo pattern (dashed) is displaced from the no echo

SATELLITE VISIBILE GRAY LEVEL

SATELLITE I.R. GRAY LEVEL

	77-92	93-108	109-124	125-140	141-156	157-172	173-188	189-205
63-68	10 / 11	5 •3	0	•	•	•	•	•
69-74	15 •15	•	•	•	•	•	•	•
75-80	20 •20	•4	•2	•	•	•	•	•
81-87	20 / 15 / 10 •10	•0 •16	•6	•7	•2	•	•	•
88-93	5 / 0 •1	•8	•6	0 / 1•9	•9	0 •2	•	•
94-99	•	•1	•4	•4	10 •12	2 / 2• •7	1 •2	1
100-105	•	•	•	•1	•2	•2	•	1
106-112	•	•	•	•	•1	•1	•	•

FIG. 16 – Number of grid points in mesonetwork with no radar echoes
(solid) and with radar echoes (dashed) 13 August 1975.
Numbers to the right of the dots are for no echoes, those
to the left for echoes.

SATELLITE VISIBILE GRAY LEVEL

SATELLITE I.R. GRAY LEVEL

	82-94	95-107	108-121	122-134	135-147	148-161	162-174	175-188
142-148	•2 0	•	0 •1 0	1•	•	•	•	•
149-155	•3	2•3	1•1	•1	•	•1	•	•
156-162	2•2 0	•3	1•2	2•5 5	•	3•2	2•	•
163-170	•	•3	•1	1•1	2•1	1•7 4•7 5 5 0		
171-177	•	•1	•1	•1	3•1	13•9 10	8•9 10 8	2•1 0
178-184	•	•	•	•1	1•4	3•3	8•7	• 0
185-191	•	•	•	1•	5•3	3•3	1•1 0	
192-199	•	•	•	•	•	2•1	3•1	•1 0

FIG. 17 – Number of grid points in mesonetwork with no radar echoes (solid) and with radar echoes (dashed) 14 August 1975. Numbers to the right of the dots are for no echoes, those to the left for echoes.

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SATELLITE VISIBILE GRAY LEVEL
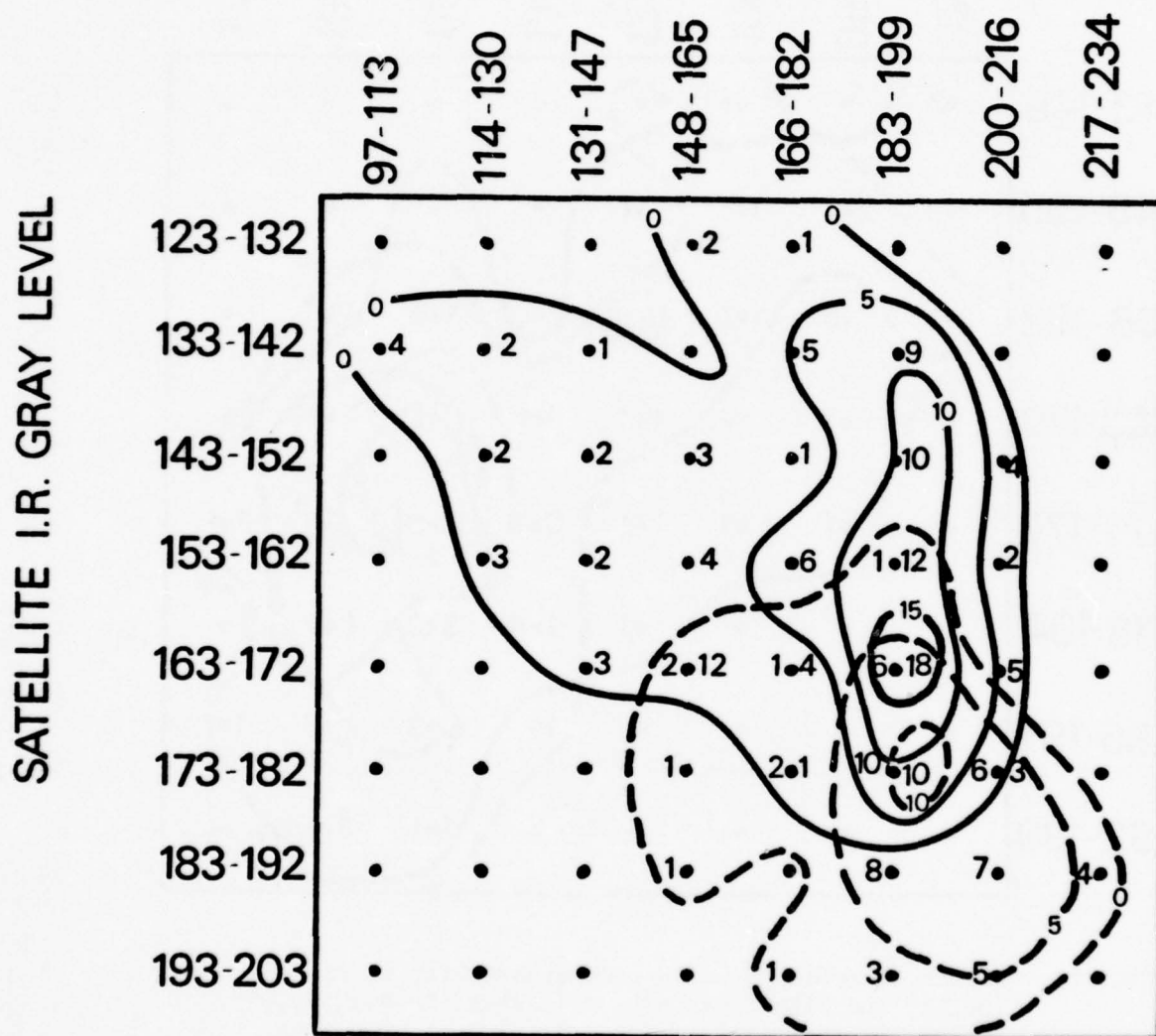
FIG. 18 - Number of grid points in mesonetwork with no radar echoes
(solid) and with radar echoes (dashed) 18 August 1975.
Numbers to the **right** of the dots are for no echoes, those
to the left for echoes.

SATELLITE VISIBILE GRAY LEVEL
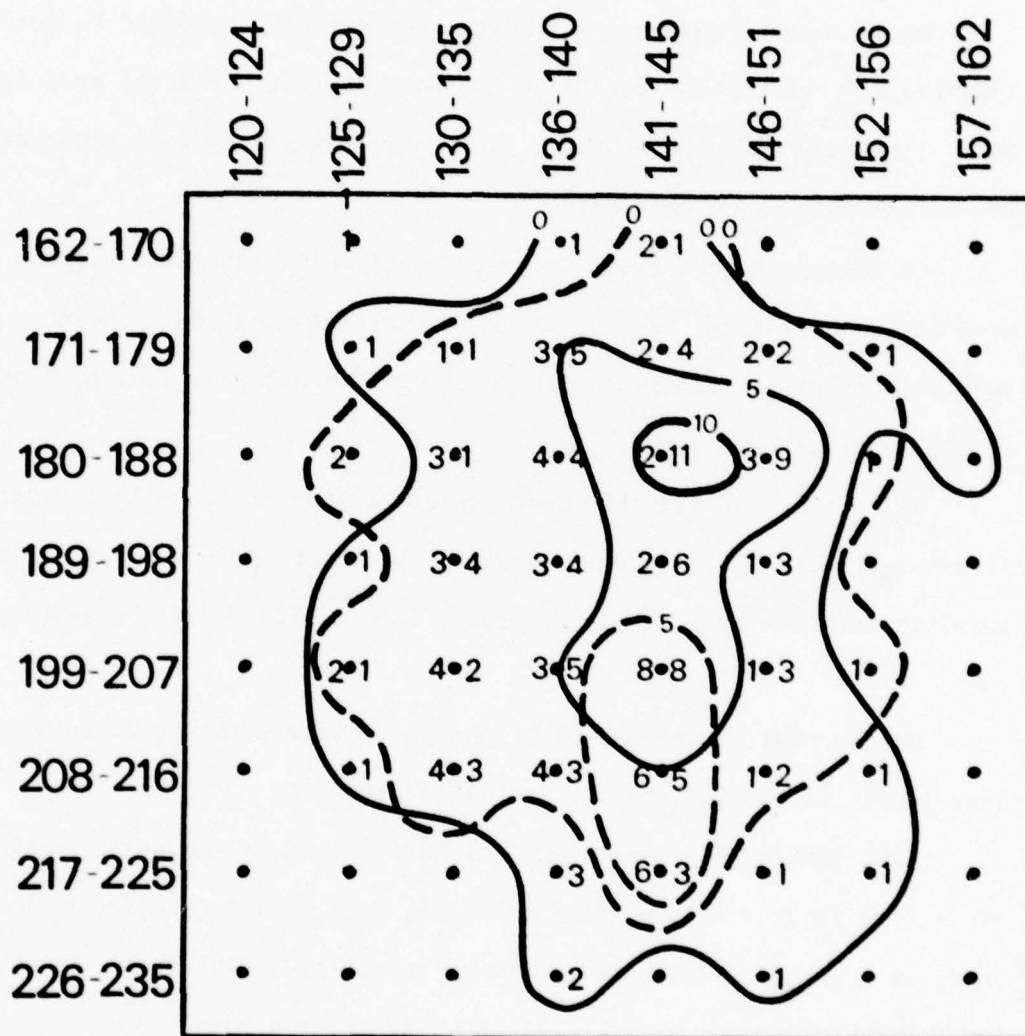
FIG. 19 – Number of grid points in mesonetwork with no radar echoes (solid) and with radar echoes (dashed) 21 August 1975. Numbers to the right of the dots are for no echoes, those to the left for echoes.

pattern (solid) in these figures. Relationships with overlapping
patterns would be a function of the position and strength of the echo
maximum with respect to the no echo maximum.

On 13 August there was an indication that echoes tended to occur
when the I.R. gray level was 94-99 and when the visible level exceeded
157. It should be noted, however, that not many echoes were observed
in the mesonetwork on that date.

On 14 August the echoes occurred mostly with satellite visible
gray levels of 148-161 and I.R. gray levels exceeding 163. There
were a substantial number of grid points with those gray levels, though,
that did not contain echoes.

The pattern on the 18th shows unique relationships with I.R. gray
levels exceeding 183. Actually most of the echoes were observed with
satellite visible gray levels exceeding 183 and I.R. levels exceeding
173.

On the 21st the echoes were observed mostly with satellite visible
gray levels of 141-145 and I.R. levels of 199-225.

Even though the film gammas may have varied, a composite of the
above four figures is presented in Figure 20. This figure shows that
there is a unique relationship between satellite visible and I.R. gray
levels exceeding 183, and the existence of radar echoes. However, most
of the echoes in these cases existed with satellite visible levels of
131-216 and I.R. levels of 163-192; and visible levels of 131-147 and
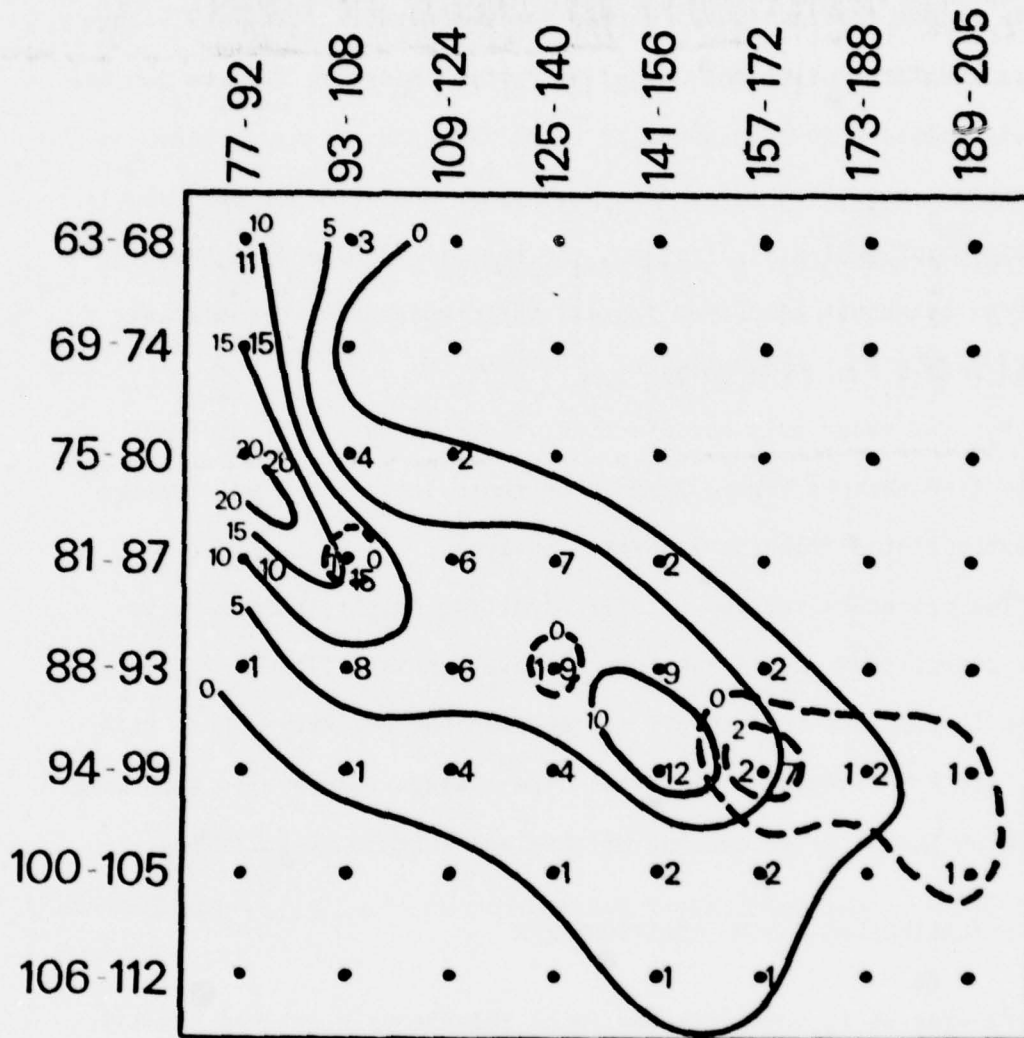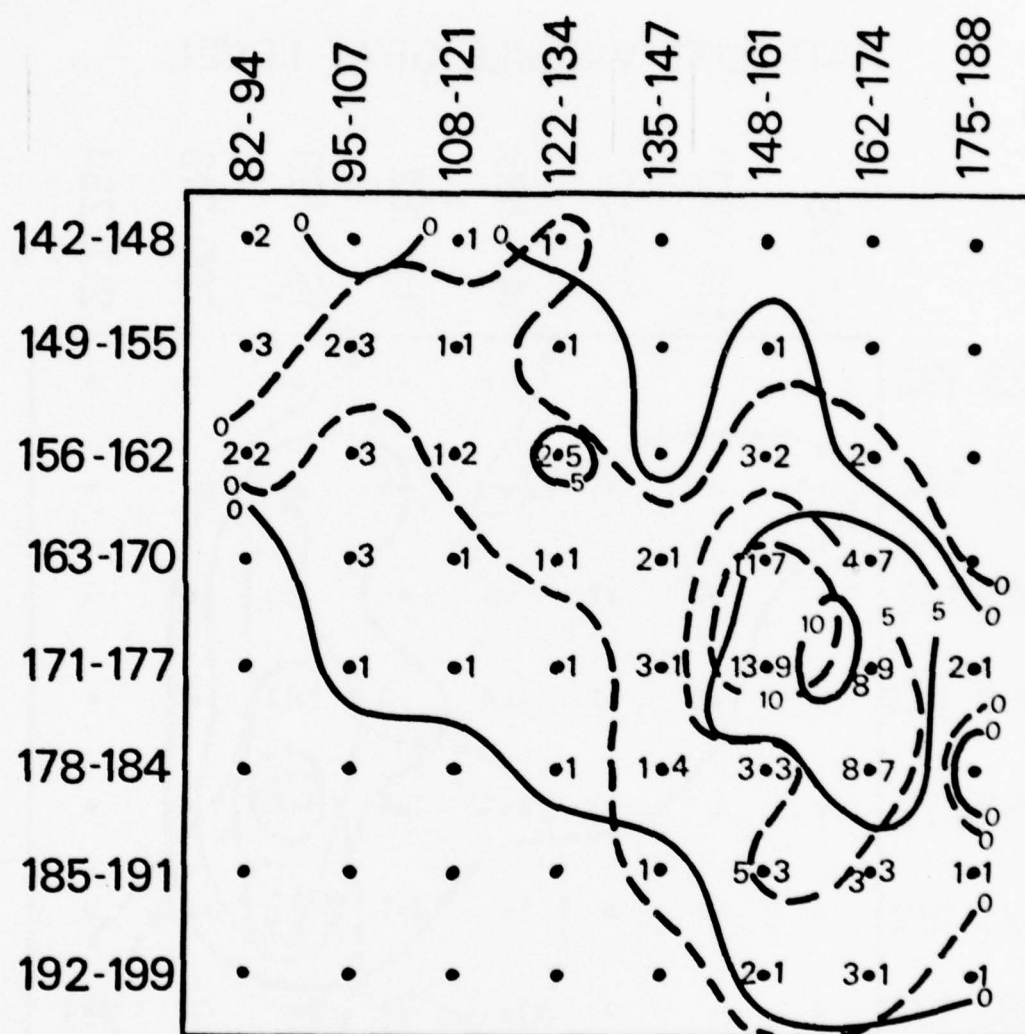I.R. levels of 193-222.
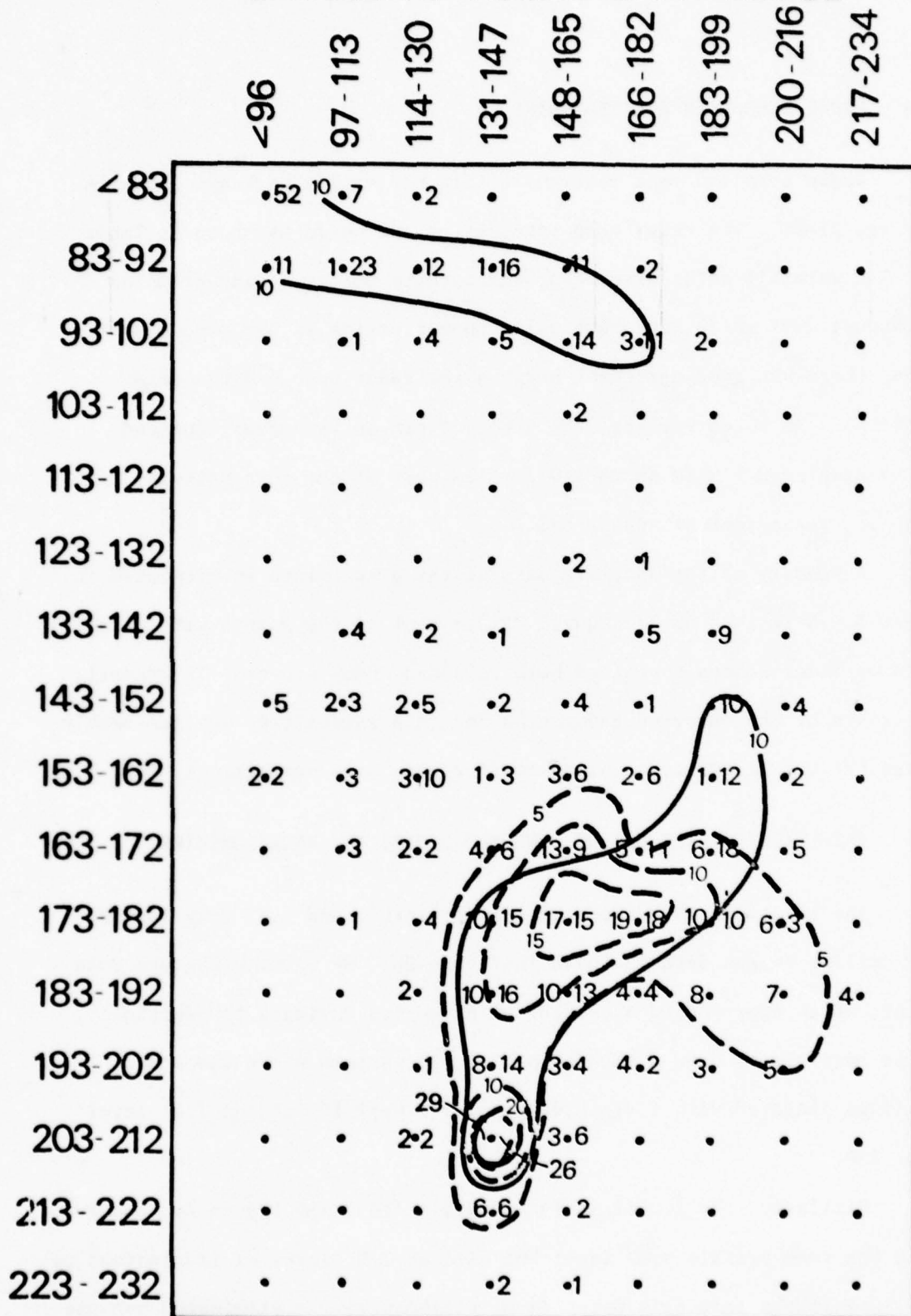
FIG. 20 - Composite number of grid points in mesonetwork with no radar echoes (solid) and with radar echoes (dashed) from all 4 cases. Numbers to the right of the dots are for no echoes, those to the left for echoes.

2.8   RADAR ECHO/RAIN RELATIONSHIPS

Radar echo and rain patterns within the mesonetwork are shown in
Figures 21-24. The radar echo intensities are coded as shown in Table
1. The rainfall rates have been converted to mm/hr. Aside from the
13 August case which had practically no convection in the mesonetwork
area, there was good agreement between the radar echo and the rain
patterns. As noted earlier, the echo pattern on 18 August appeared
to be displaced 1 mile south and 3 miles west of the rain pattern, but
even so, the agreement wasn't bad.

A summary of the specific data at the grid points is presented in
Table 3. Note that on 14 August, 72 per cent of the points with either
rain or radar echoes contained both rain and radar echoes. In general,
the range of the observed radar echo and rain intensities was reasonably
close but the linear correlation coefficients were surprisingly low.

2.9   SATELLITE/CEILING HEIGHT, SURFACE VISIBILITY RELATIONSHIPS

The relationship between satellite visible and I.R. gray levels,
and ceiling height data is shown in Figure 25. By eliminating one data
point, which represented a ceiling at Ft. Myers during a thundershower,
it is possible to draw a smooth, bull's eye pattern where the lowest
ceilings occurred with a visible gray level near 100 and an I.R. level
near 130.

Similarly, the lowest surface visibilities, see Figure 26, occurred
with the same visible gray level but with an I.R. level of 110 instead of
130. Again the same data point (4 mi visibility) was eliminated because
it was related to an active thundershower at Ft. Myers.
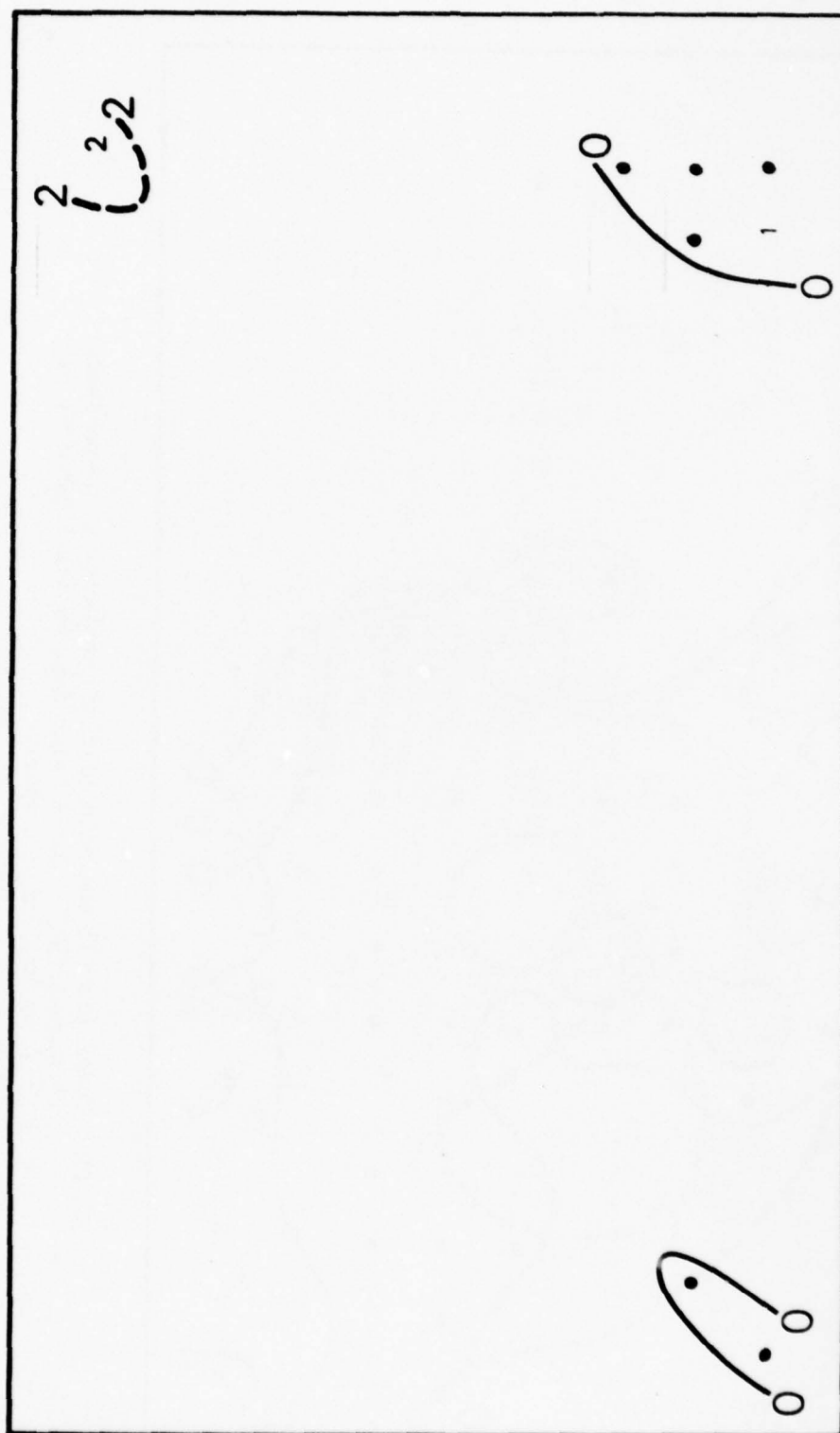
FIG. 21 - Radar (solid) and rain (dashed) patterns in mesonetwork 13 August 1975. Coded radar data in small numbers; rain data, mm/hr, large numbers.

32
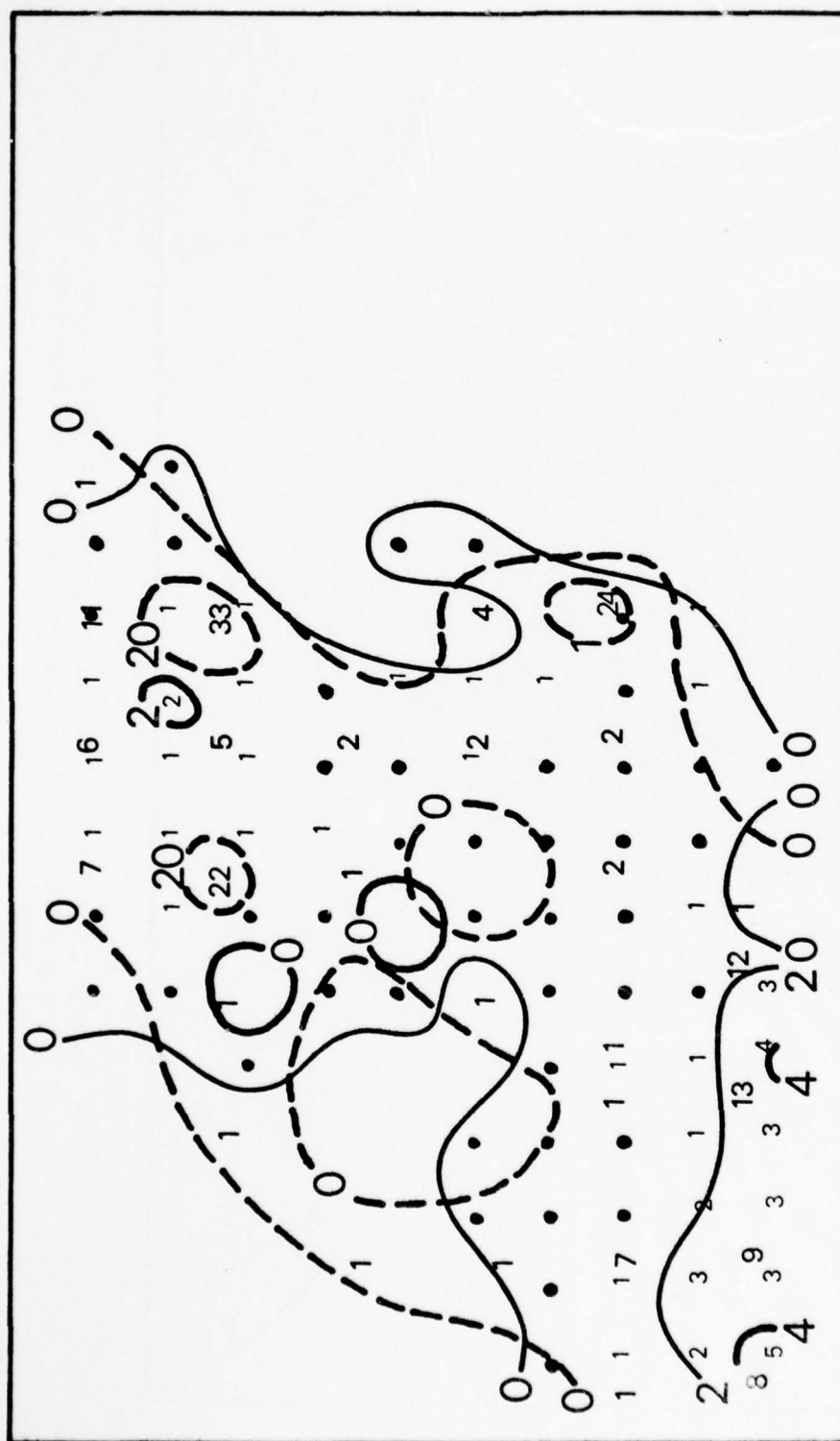
FIG. 22 - Radar (solid) and rain (dashed) patterns in mesonetwork
14 August 1975. Coded radar data in small numbers; rain
data, mm/hr, large numbers.
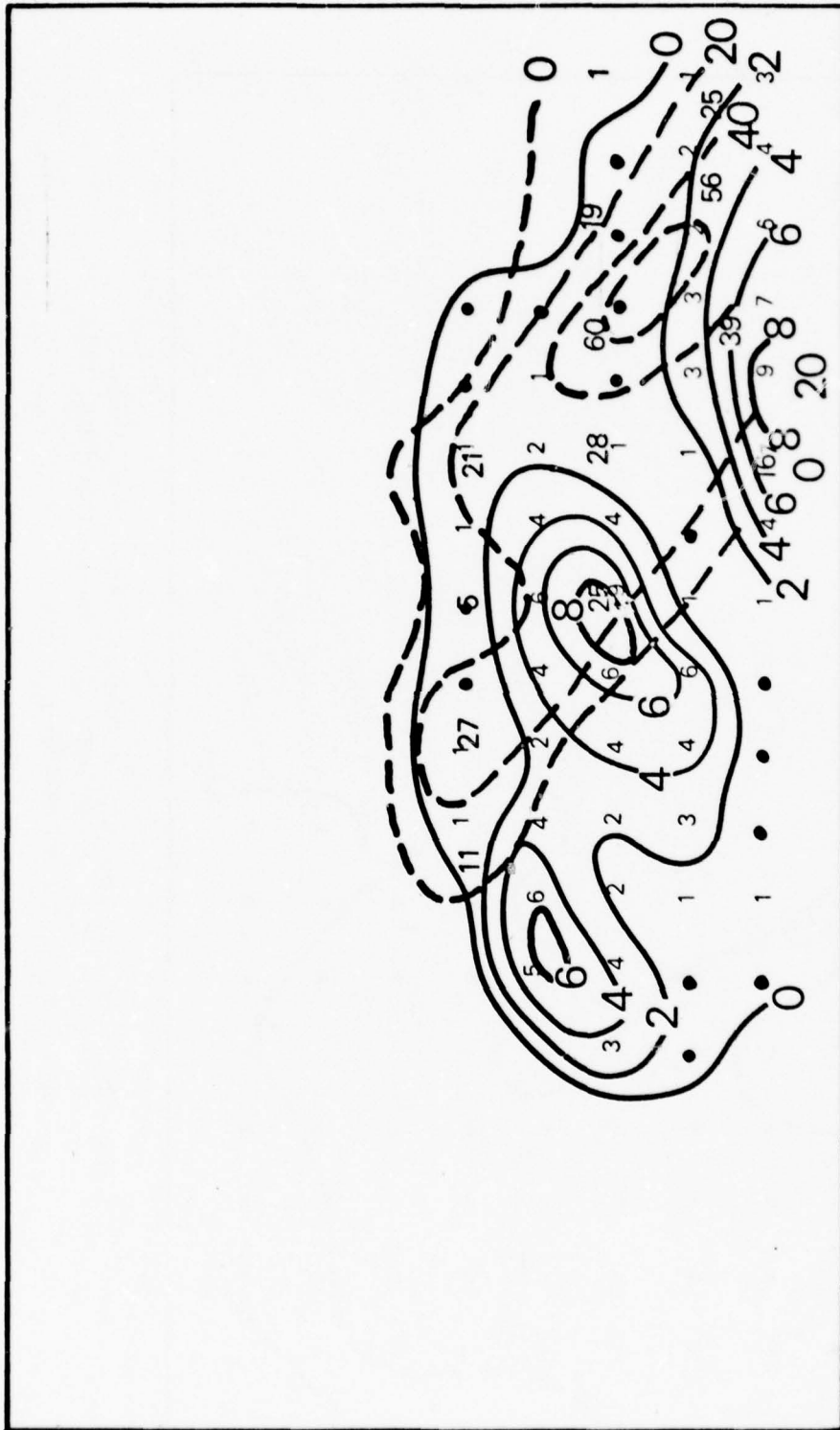
FIG. 23 - Radar (solid) and rain (dashed) patterns in mesonetwork 18 August 1975. Coded radar data in small numbers; rain data, mm/hr, large numbers.

34
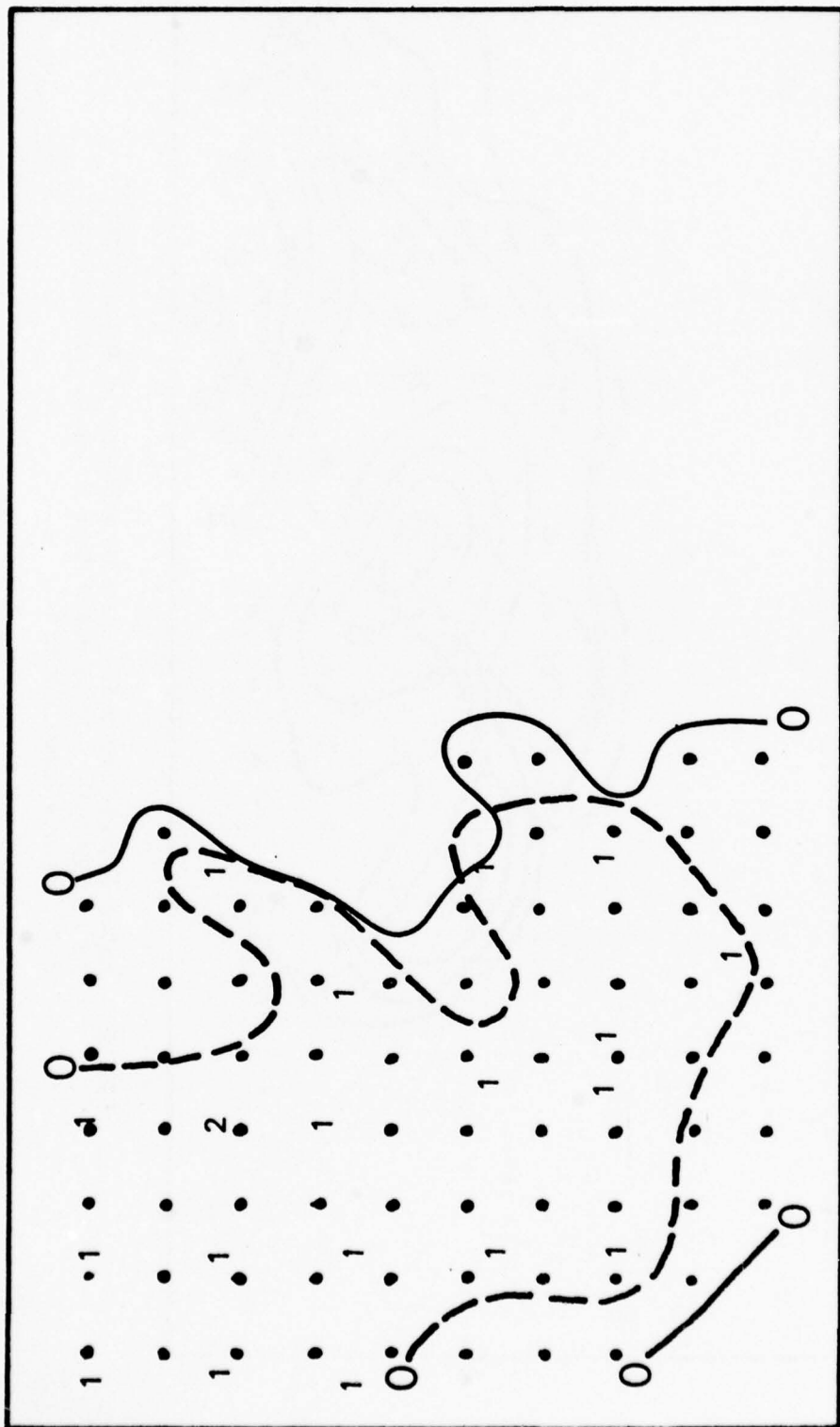
FIG. 24 - Radar (solid) and rain (dashed) patterns in mesonetwork 21 August 1975. Coded radar data in small numbers; rain data, mm/hr, large numbers.

	13 AUG 75	14 AUG 75	18 AUG 75	21 AUG 75
Total Number of Grid Points	180	180	180	180
With No Rain Nor Radar Echo	172	91	118	104
With Either Rain or Radar Echo	8	89	62	76
With Rain	1	75	37	48
With Radar Echo	7	78	58	75
With Rain and Radar Echo	0	64	33	47
With Rain But No Radar Echo	1	11	4	1
With Radar Echo But No Rain	7	14	25	28
Percentage of Points With Either Rain or Radar Echo That Include Both Rain and Radar Echo	-	72	53	62
Time of Rain Data (Z)	2130 - 2145	1930 - 1945	1915 - 1930	2115 - 2130
Time of Radar Data (Z)	2130	1930	1915	2110
Range of Rain Data (mm/hr)	0 - 2	0 - 22	0 - 60	0 - 2
Range of Radar Data (mm/hr)	3.1 - 12.3	1.6 - 19.6	1.7 - 33.3	2.4 - 4.8
Linear Correlation Coefficient Between Rain Intensity and Radar Echo Intensity	Small Sample	0.19	0.02	0.01

TABLE 3 - Grid Point Comparison of Rain and Radar Echo Data in FACE Mesonetwork.
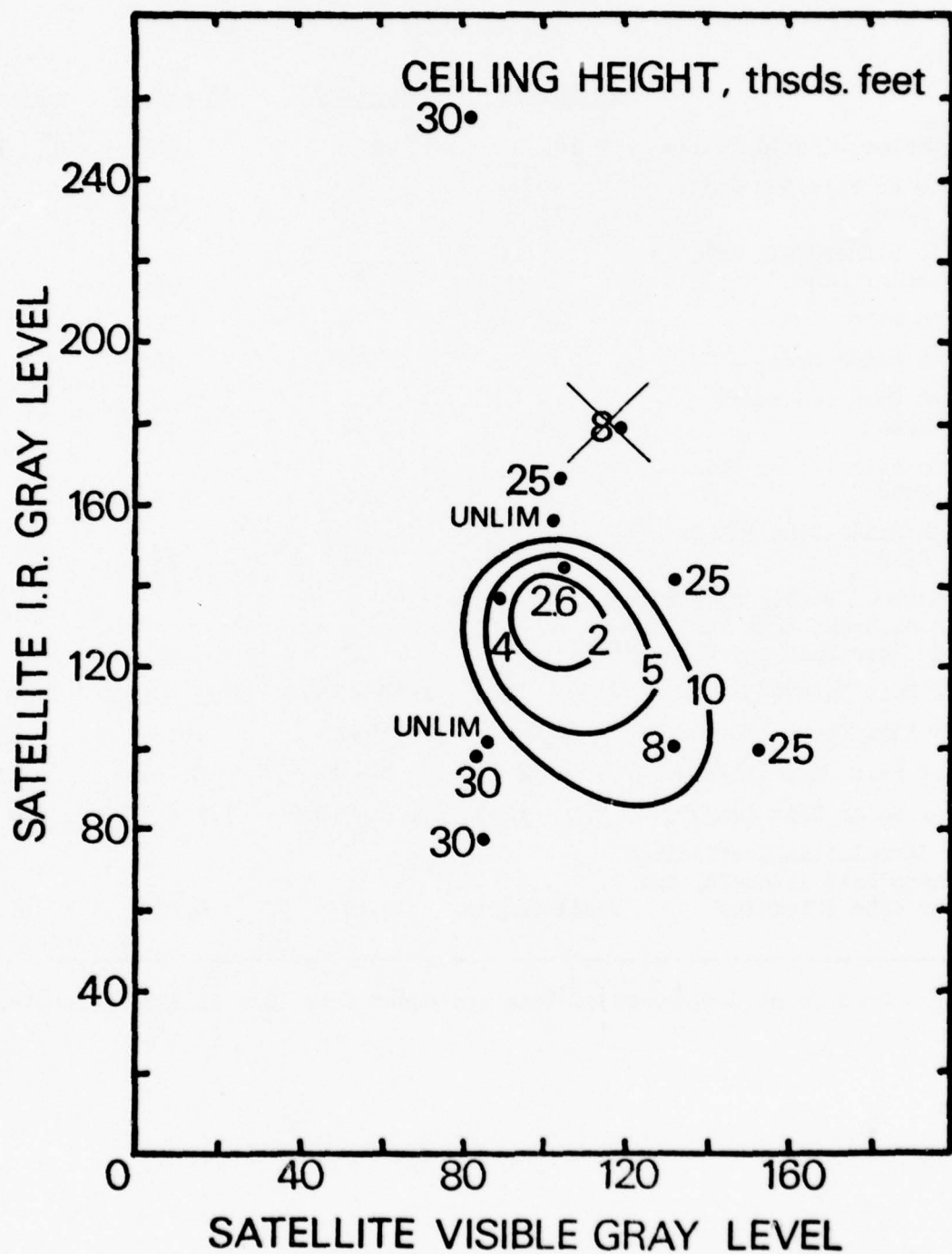
FIG. 25 - Ceiling height vs. satellite visible and I.R. gray level.
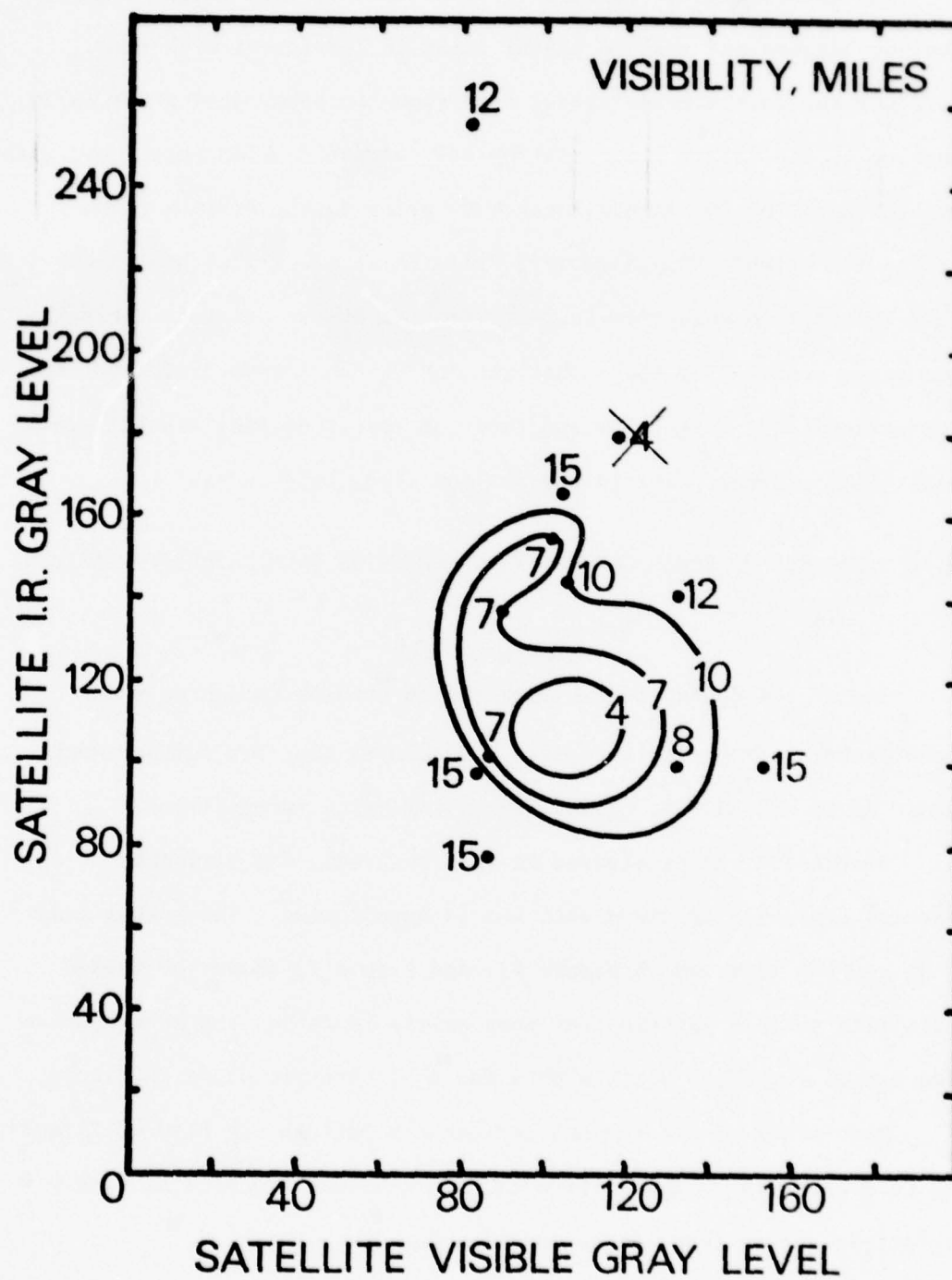
FIG. 26 - Surface visibility vs. satellite visible and I.R. gray level.

The observation of relatively low satellite gray levels with low ceiling heights and surface visibilities is consistent with the tendency for such meteorological conditions to occur during the early portion of the mature stage of tropical cumulus development, i.e., with the onslaught of the rainfall which is prior to the maximum cloud growth and brightness. Moreover, Griffith et al. (1976) have shown that the maximum echo area in South Florida occurs prior to the maximum cloud area. From those observations it can also be inferred that the maximum echo brightness and thus the lowest ceiling and surface visibilities occur prior to the maximum cloud brightness.

2.10   EXAMPLE OF RADAR ECHO PATTERN DEPICTION FROM SATELLITE VISIBLE DATA

One of the goals of this work was to attempt to depict radar echo patterns from satellite data. A natural goal for further work would be to extend that capability to intensity recognition.

Of the four cases studied in this contract, the best echo pattern depiction occurred with the 14 August case. The actual radar echo pattern is shown in Figure 27, and Figure 28 shows the themed satellite visible pattern that most nearly resembled the echo pattern. The actual satellite visible data for this case are shown in Figure 13. The rather good agreement between the patterns in Figures 27 and 28 is encouraging. The pattern in Figure 28 was produced by simply selecting a gray level range and then pushing a button.

FIG. 27 - Actual radar echo pattern, 14 August 1975 case
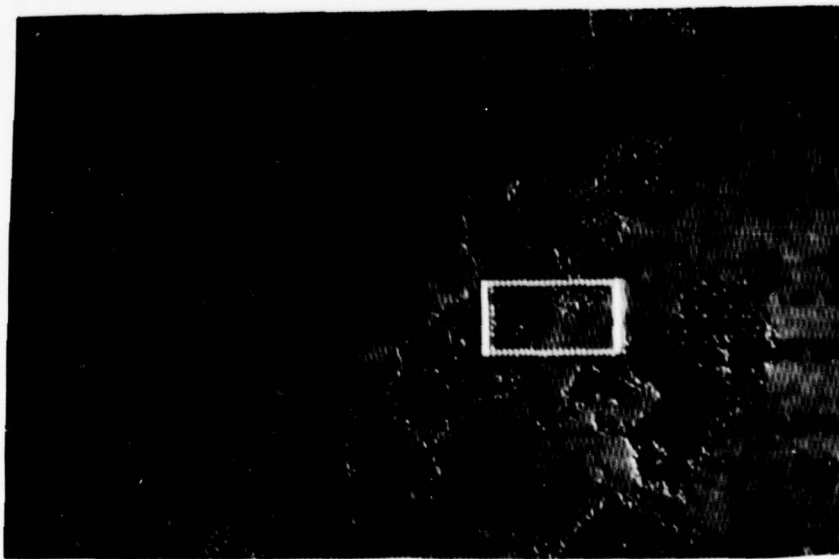
FIG. 28 - Simulated radar echo pattern produced from themed satellite visible data, 14 August 1975 case

ACKNOWLEDGEMENTS

We are grateful to the National Hurricane and Experimental Meteorology Laboratory for providing digital radar, rain gauge and radiosonde data; to the Satellite Field Services Station in Miami and the Atmospheric Science Laboratory, WSMR, for providing satellite data; to the National Climatic Center for providing surface observations; and to the Kennedy Space Center Data Analysis Facility for their role in analyzing the satellite and radar data on the Image 100 system.

The difficult task of overcoming the computer incompatibilities was accomplished by Bob Orgaz who produced the programs in the appendix. Ms. Lynn Zakevich-Gheer drafted the figures.

We are especially appreciative to Mr. Bruce Miers (WSMR) for his prompt assistance and overall efficiency as contract monitor, and to Mr. Stormy Horn (WSMR) for his role in arranging analytical time on the KSC Image 100 system. The concern and support of the Atmospheric Sciences Laboratory, WSMR, is gratefully acknowledged.

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APPENDIX

COMPUTER PROGRAMS FOR CONVERTING 7-TRACK NHEML KART DIGITAL
TAPES TO 9-TRACK TAPES WITH SUITABLE BLOCK SIZE AND FORMAT
FOR THE KSC PDP 11/35 COMPUTER SYSTEM

UNIVAC whole words: 16,381

WORD 1		WORD 2		WORD 3				WORD 16380	16381	
½	½	½	½							/////
1	2	3	4	5	6	7		32760	32761	

PLUS 7 whole words

THERE ARE 32762 HALF WORDS (181 × 181)

INPUT TAPE

Program to Reblock Input Array of 16381 UNIVAC words to 32 blocks of 514 words

OUTPUT TAPE

Block 1	Block 2	3			31	32
1-514	515-1028	1029-1542			15451-15964	16381
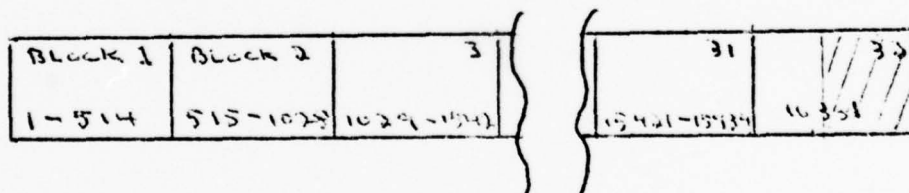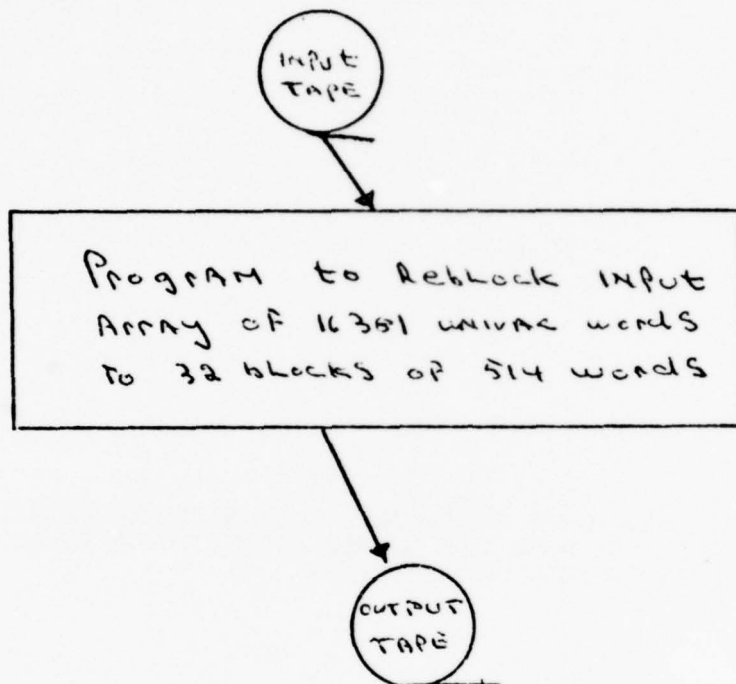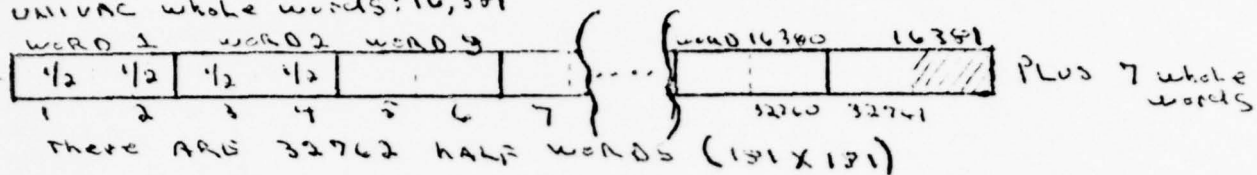
QI   FOR DLL,DBL   .
UNIVAC 1108 FORTRAN V LEVEL   2206 0018 F5018P
THIS COMPILATION WAS DONE ON 19 FEB 76 AT 12:28:57

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

```
      0001    *CODE    000071
      0000    *DATA    040122
      0002    *BLANK   000000
```

EXTERNAL REFERENCES (BLOCK, NAME)

```
      0003    NTRAN
      0004    EXIT
      0005    NWDU$
      0006    NIO2$
      0007    NSTOP$
```

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

```
   0001   000004 1L          0001   000042 105L        0001   000026 115G
   0001   000057 500L        0000 I 000011 I           0000 I 000003 IC
   0000 I 000002 LS          0000 I 000000 L1          0000 I 000001 L2
```

```
00101      1*          DIMENSION I(16388),J(514,32)
00103      2*          EQUIVALENCE (I,J)
00104      3*          L1=16388
00105      4*          L2=514
00106      5*        1 CALL NTRAN(7,2,L1,I,LS)
00107      6*        5 IF(LS.EQ.-1) GO TO 5
00111      7*          IF(LS.EQ.-2) GO TO 500
00113      8*          IC=0
00114      9*          DO 110 N=1,32
00117     10*          IC=IC+1
00120     11*          CALL NTRAN(9,1,L2,J(1,N),IS)
00121     12*      105 IF(IS.EQ.-1) GO TO 105
00123     13*      110 CONTINUE
00125     14*          WRITE(6,120) IC
00130     15*      120 FORMAT(1X,'COUNT=',I3)
00131     16*          GO TO 1
00132     17*      500 CONTINUE
00133     18*          CALL NTRAN(8,9,9,10)
00134     19*          CALL EXIT
00135     20*          END
```

END OF UNIVAC 1108 FORTRAN V COMPILATION.   0 *DIAGNOSTIC* MESSAGE(
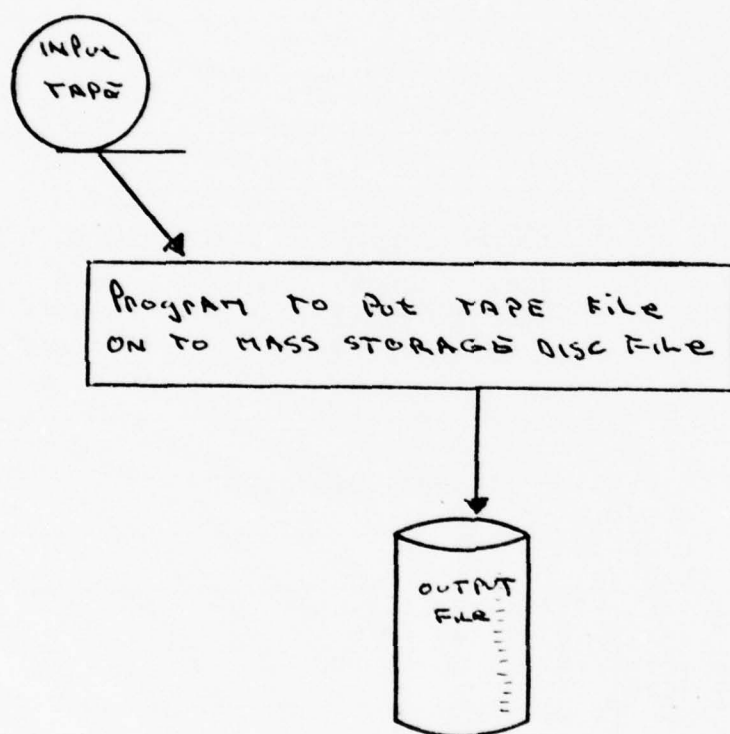
@RUN ORGM36,006626,ORGAZ
```
*****************************************************
*****************************************************
******    R E M I N D E R  T O  A L L  U S E R S    ******
*****************************************************
* A USERID WILL BE REQUIRED ON -ALL- RUN STATEMENTS AFTER *
* MAY 31, 1976.  STUDENT AUTHORIZATION CARDS WILL INCLUDE *
* THE USERID. ALL OTHERS PLEASE CONTACT COMPUTER SERVICES *
* DISPATCH OFFICE FOR FORMS AND INFORMATION............... *
*****************************************************
*****************************************************
```
@FOR,IS
FOR S11A-05/12/76-13:07:17

    MAIN PROGRAM

    STORAGE USED: CODE(1) 000052; DATA(0) 001017; BLANK COMMON(2) 000000

    EXTERNAL REFERENCES (BLOCK, NAME)

       0003   NTRAN
       0004   EXIT
       0005   NINTR$
       0006   NWDU$
       0007   NIO2$
       0010   NSTOP$

    STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

       0001   000004 105G   0000   001004 110F   0001   000041 9999L   0000
       0000 I 001003 L

```
00101     1*           IMPLICIT INTEGER(A-Z)
00103     2*           DIMENSION A(514)
00104     3*           DO 3000 II=1,32
00107     4*           CALL NTRAN(4,2,514,A,L)
00110     5*           CALL NTRAN(4,22)
00111     6*           IF(L.EQ.-2) GO TO 9999
00113     7*           CALL NTRAN(3,1,514,A,L)
00114     8*           CALL NTRAN(3,22)
00115     9*      3000 CONTINUE
00117    10*      9999 CONTINUE
00120    11*           WRITE(6,110)
00122    12*       110 FORMAT(1X,'COMPLETE')
00123    13*           CALL EXIT
00124    14*           END
```

       END OF COMPILATION: NO DIAGNOSTICS.
@ASG,T INTAPE,16N,RNW226
@USE 4,,INTAPE
@ASG,CP HL226,

INPUT
FILE

32 Blocks
each

514 words

Program to Reblock
The 32 blocks 514 words
to 3 blocks 5654 words

OUTPUT
FILE

3 Blocks
each
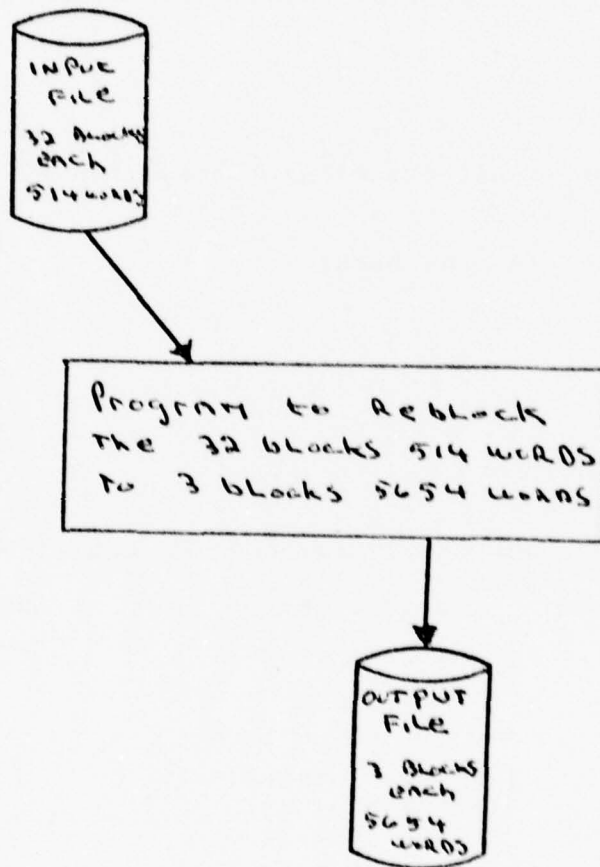
5654
words

```
ORGAZ*DWN.P1
      1              IMPLICIT INTEGER(A-Z)
      2              DIMENSION A(514),B(5654)
      3              K1=1
      4              K2=11
      5              KC=1
      6          10 CONTINUE
      7              K=1
      8              DO 25 I=K1,K2
      9              CALL NTRAN(4,2,514,A,L)
     10              CALL NTRAN(4,22)
     11              DO 20 J=1,514
     12              B(K)=A(J)
     13              K=K+1
     14          20 CONTINUE
     15          25 CONTINUE
     16              IF(KC.EQ.3) GO TO 30
     17              GO TO 35
     18          30 CONTINUE
     19              DO 33 K=5141,5654
     20          33 B(K)=0
     21          35 CONTINUE
     22              CALL NTRAN(3,1,5654,B,L)
     23              CALL NTRAN(3,22)
     24              K1=K1+11
     25              K2=K2+11
     26              IF(K2.EQ.33) K2=32
     27              KC=KC+1
     28              IF(KC.EQ.4) GO TO 100
     29              GO TO 10
     30         100 CONTINUE
     31              WRITE(6,110)
     32         110 FORMAT(1X,'COMPLETE')
     33              CALL EXIT
     34              END
OPFT,S DWN.P2
```
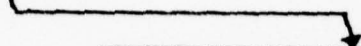
50

INPUT FILE

Program to create a new file with the last word first and first word last.
Then
Reorder each half word to make a continuous string of numbers from 32,762 to 1

OUTPUT FILE

INPUT FILE

UNIVAC

WORD 1		WORD 2		3		4			16 380		16 381	
DATA POINT									32759	32760		
1	2	3	4	5	6	7	8				32761	32762

UNIVAC WORD

16 381		16 380		WORD 4		3		2		1	
DATA POINT	32762		32760	DATA POINT							
32761		32759		7	8	5	6	3	4	1	2

OUTPUT FILE

UNIVAC WORD

16 381		16 380		WORD 4		3		2		1	
DATA POINT		32760		DATA POINT							
32762	32761		32759	8	7	6	5	4	3	2	1
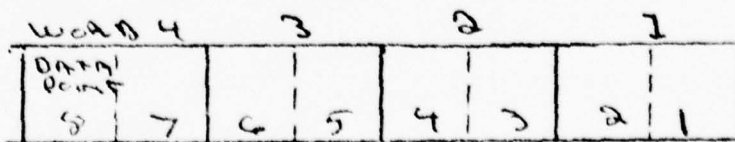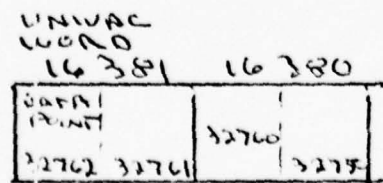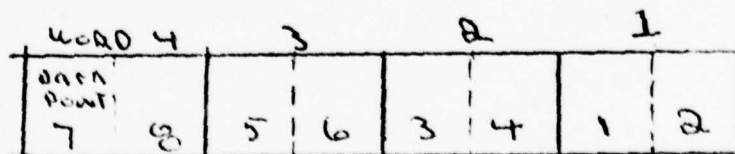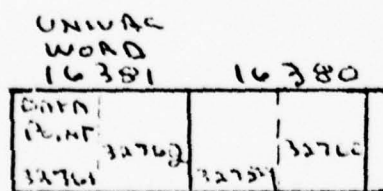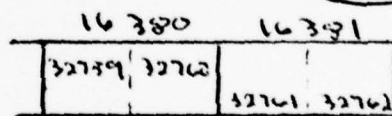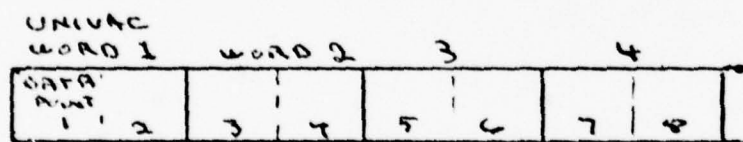
```
ORGAZ*DWN.P2
    1              IMPLICIT INTEGER(A-Z)
    2              DIMENSION A(5654),B(5654)
    3              DO 10 I=1,2
    4              CALL NTRAN(4,2,5654,A,L)
    5              CALL NTRAN(4,22)
    6          10 CONTINUE
    7              K=1
    8              CALL NTRAN(4,2,5654,A,L)
    9              CALL NTRAN(4,22)
   10              DO 20 I=5654,1
   11              FLD(0,18,B(K))=FLD(18,18,A(I))
   12              FLD(18,18,B(K))=FLD(0,18,A(I))
   13              K=K+1
   14          20 CONTINUE
   15              CALL NTRAN(3,1,5654,B,L)
   16              CALL NTRAN(3,22)
   17              CALL NTRAN(4,10)
   18              CALL NTRAN(4,22)
   19              CALL NTRAN(4,2,5654,A,L)
   20              CALL NTRAN(4,22)
   21              K=1
   22              CALL NTRAN(4,2,5654,A,L)
   23              CALL NTRAN(4,22)
   24              DO 25 I=5654,1
   25              FLD(0,18,B(K))=FLD(18,18,A(I))
   26              FLD(18,18,B(K))=FLD(0,18,A(I))
   27              K=K+1
   28          25 CONTINUE
   29              CALL NTRAN(3,1,5654,B,L)
   30              CALL NTRAN(3,22)
   31              CALL NTRAN(4,10)
   32              CALL NTRAN(4,22)
   33              K=1
   34              CALL NTRAN(4,2,5654,A,L)
   35              CALL NTRAN(4,22)
   36              DO 30 I=5654,1
   37              FLD(0,18,B(K))=FLD(18,18,A(I))
   38              FLD(18,18,B(K))=FLD(0,18,A(I))
   39              K=K+1
   40          30 CONTINUE
   41              CALL NTRAN(3,1,5654,B,L)
   42              CALL NTRAN(3,22)
   43              WRITE(6,110)
   44         110 FORMAT(1X,'COMPLETE')
   45              CALL EXIT
   46              END
6PRT,S DWN.S1
```

INPUT
FILE

OUT
PUT
FILE
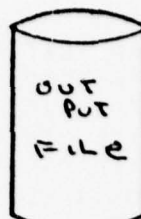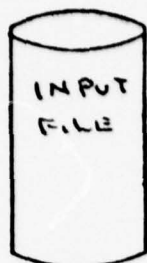
The univac 1100 has 36 bits
per word or 18 bits per half
word. The PDP has 16 bits
per word. This program
generates a new data file
by taking away the leading
2 bits from each original
univac half word and dumps
the remaining 16 bits into
a new string of 36 bits
univac words.

For every 8 words in
the new string

$$\left[\frac{8 \text{ univac words} \times 36 \text{ bits/word}}{16 \text{ bits/PDP word}} \right]$$

18 PDP words are generated.

```
OR.AZ*DWN.S1
    1               IMPLICIT INTEGER(A-Z)
    2               DIMENSION KO(352)
    3               DIMENSION D(1905),E(1223),F(941)
    4               DIMENSION A(8000),B(2816),C(5654)
    5               DIMENSION X1(24),Y1(24),X2(24),Y2(24)
    6               READ(2,1) X1
    7               READ(2,1) Y1
    8               READ(2,1) X2
    9               READ(2,1) Y2
   10           1 FORMAT(24I2)
   11               CALL NTRAN(4,2,5654,C,L)
   12               CALL NTRAN(4,22)
   13               J1=2
   14               DO 1000 I=1,8000
   15        1000 A(I)=0
   16               JB=0
   17               DO 600 JA=582,5654
   18               JB=JB+1
   19         600 A(JB)=C(JA)
   20               JTEST=1
   21         216 CONTINUE
   22               ITEST=1
   23               K=0
   24               J=-1
   25           2 CONTINUE
   26               DO 30 KK=1,352
   27               I=0
   28               DO 20 I1=1,2
   29               K=K+1
   30               DO 5 I2=1,2
   31               I=I+1
   32               J=J+1
   33               M=J/3+1
   34           5 FLD(X1(I),Y1(I),B(M))=FLD(X2(I),Y2(I),A(K))
   35               DO 15 I3=1,3
   36               K=K+1
   37               DO 10 I4=1,3
   38               I=I+1
   39               J=J+1
   40               M=J/3+1
   41          10 FLD(X1(I),Y1(I),B(M))=FLD(X2(I),Y2(I),A(K))
   42          15 CONTINUE
   43          20 CONTINUE
   44               K=K+1
   45               DO 25 I5=1,2
   46               I=I+1
   47               J=J+1
   48               M=J/3+1
   49          25 FLD(X1(I),Y1(I),B(M))=FLD(X2(I),Y2(I),A(K))
   50          30 CONTINUE
   51               DO 873 OZ=1,352
   52         873 RO(OZ)=B(OZ)
   53               CALL NTRAN(3,1,2816,B,L)
   54               CALL NTRAN(3,22)
   55               ITEST=ITEST+1
   56               IF(ITEST.GE.2) K=3168
```

```
57          IF(ITEST.LT.J1) GO TO 2
58          IF(JTEST.EQ.1) GO TO 695
59          IF(JTEST.EQ.2) GO TO 795
60          IF(JTEST.EQ.3) GO TO 895
61          IF(JTEST.EQ.4) GO TO 999
62      695 JB=0
63          DO 700 JA=3169,5073
64          JB=JB+1
65      700 D(JB)=A(JA)
66          DO 701 LP=1,8000
67      701 A(LP)=0
68          CALL NTRAN(4,2,5654,C,L)
69          CALL NTRAN(4,22)
70          DO 710 JA=1,1905
71      710 A(JA)=D(JA)
72          JB=1905
73          DO 715 JA=1,5654
74          JB=JB+1
75      715 A(JB)=C(JA)
76          JTEST=JTEST+1
77          J1=3
78          GO TO 216
79      795 JB=0
80          DO 800 JA=6337,7559
81          JB=JB+1
82      800 E(JB)=A(JA)
83          DO 801 LP=1,8000
84      801 A(LP)=0
85          CALL NTRAN(4,2,5654,C,L)
86          CALL NTRAN(4,22)
87          DO 810 JA=1,1223
88      810 A(JA)=E(JA)
89          JB=1223
90          DO 815 JA=1,5654
91          JB=JB+1
92      815 A(JB)=C(JA)
93          JTEST=JTEST+1
94          J1=3
95          GO TO 216
96      895 JB=0
97          DO 900 JA=6337,6877
98          JB=JB+1
99      900 F(JB)=A(JA)
100         DO 901 LP=1,8000
101     901 A(LP)=0
102         DO 905 JA=1,541
103     905 A(JA)=F(JA)
104         DO 915 JA=542,4000
105     915 A(JA)=0
106         J1=2
107         JTEST=JTEST+1
108         GO TO 216
109     999 CONTINUE
110         WRITE(6,2000)
111    2000 FORMAT(1X,'COMPLETE')
112         CALL EXIT
113         END
```

56

```
ORGAZ*DWN.D1
    1        0016320012290009240004200016320012280308240004 20
    2        1616041216080816120416161616004121508094161204 1616
    3        G2200206200210200214200220002324022028022032 0220
    4        161604121608081612041616160041216080916120416 16
JPET,S DWN.D2
```

INPUT
FILE

OUT
PUT
FILE
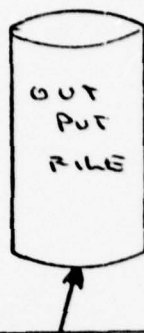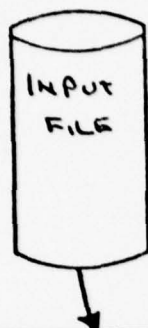
The PDP has 16 bits per word or 8 bits per half word. This computer reads the second half word first (bits 9-16) and the first half word second (bits 1-8) This program generates a new data file by alternating every 8 bits in the string of words generated by the program that eliminates the leading 2 bits of each half word in the original data set.

The highest numbers
are the list of the minimum
elements.

String of numbers.

The numbers
each specify a
number within list
in the corresponding list
numbers from the program
generated by the program
that eliminates
the list of all these in the
in the originalizing in
the set stated.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
NEW WORD 1 =																																					
2 =																																					
3 =																																					
4 =																																					

```
OR SAZ*DWN.S2
    1              IMPLICIT INTEGER(A-Z)
    2              DIMENSION A(2816),B(2916)
    3              DIMENSION X1(22),X2(22),Y1(22),Y2(22)
    4              DIMENSION Z1(22),Z2(22)
    5              DIMENSION ZA(22),ZB(22)
    6              READ(7,1) X1
    7              READ(7,1) Y1
    8              READ(7,1) Z1
    9              READ(7,1) X2
   10              READ(7,1) Y2
   11              READ(7,1) Z2
   12            1 FORMAT(22I2)
   13              DO 201 LP=1,22
   14              ZA(LP)=Z1(LP)
   15          201 ZB(LP)=Z2(LP)
   16              DO 600 LP=1,6
   17              CALL NTRAN(4,2,2816,A,L)
   18              CALL NTRAN(4,22)
   19              DO 500 I1=1,704
   20              DO 450 I=1,22
   21              M=Z1(I)
   22              K=Z2(I)
   23              FLD(X1(I),Y1(I),B(M))=FLD(X2(I),Y2(I),A(K))
   24          450 CONTINUE
   25              DO 475 J=1,22
   26              Z1(J)=Z1(J)+4
   27          475 Z2(J)=Z2(J)+4
   28          500 CONTINUE
   29              CALL NTRAN(3,1,2816,B,L)
   30              CALL NTRAN(3,22)
   31              DO 425 LZ=1,22
   32              Z1(LZ)=ZA(LZ)
   33          425 Z2(LZ)=ZB(LZ)
   34          600 CONTINUE
   35              WRITE(6,700)
   36          700 FORMAT(1X,'COMPLETE')
   37              CALL EXIT
   38              END
QPRT,S DWN.D1
```

```
OR GAZ*DWN.D2
    1        00081624320004081220280008162428320004122028
    2        080908080804040404080808080308040404040408080808
    3        01010101010202020202020203030303030304040404040404
    4        080924160409320020120028160832002428120428 20
    5        03080808040404040808080808080840404040803080808
    6        0101010102020102020203020303030304030304040404
aFIN
```

Program to Reblock
input Mass storage
Disc File (UNIVAC 1100)
(2816 words to 352
words) and outputs
a Tape File For
the PDP
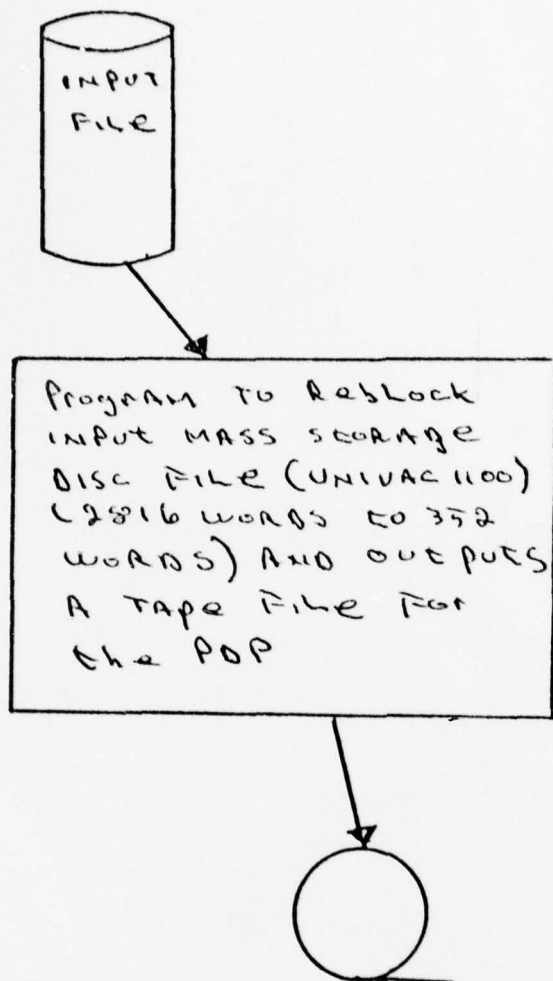
```
@FOR,IS
FOR S11A-06/09/76-11:42:43

    MAIN PROGRAM

    STORAGE USED: CODE(1) 000065; DATA(0) 006164; BLANK COMMON(2) 000000


    EXTERNAL REFERENCES (BLOCK, NAME)

      0003    NTRAN
      0004    EXIT
      0005    NINTR$
      0006    NWDU$
      0007    NIO2$
      0010    NSTOP$


    STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

      0001    000003 105G      0000    006145 110F      0001    000020 113G      000
      0000 I 005400 B          0000 I 006140 I          0000 I 006143 J          000
      0000 I 006141 N


    00101      1*              IMPLICIT INTEGER(A-Z)
    00103      2*              DIMENSION A(2816),B(352)
    00104      3*              DO 30 I=1,6
    00107      4*              N=0
    00110      5*              CALL NTRAN(4,2,2816,A,L)
    00111      6*              CALL NTRAN(4,22)
    00112      7*              DO 25 J=1,8
    00115      8*              DO 20 K=1,352
    00120      9*              N=N+1
    00121     10*           20 B(K)=A(N)
    00123     11*              CALL NTRAN(3,1,352,B,L)
    00124     12*              CALL NTRAN(3,22)
    00125     13*           25 CONTINUE
    00127     14*           30 CONTINUE
    00131     15*              CALL NTRAN(3,9,9,10)
    00132     16*              WRITE(6,110)
    00134     17*          110 FORMAT(1X,'COMPLETE')
    00135     18*              CALL EXIT
    00136     19*              END


        END OF COMPILATION:        NO  DIAGNOSTICS.
@ASG,A Z4.
@USE 4.,Z4.
@ASG,TH  OUTAPE,16N,MEDPLT
@USE  3.,OUTAPE.
@XQT
RMAP-9-06/09-11:43
```

INPUT TAPE

OUTPUT TAPE

This program reads an input tape generated by the univac 1100 computer for the PDP computer. An array of 181 PDP words are read at a time. It inverts the array making the 1st value the 181st value. It fills the array with leading and trailing zero's. This array is then outputed to another tape for the cape.

64

PDP WORDS (16 bits)

INPUT

DATA POINT 32761	32760	32759	32755	...	32581	32580

OUTPUT ⓪

DATA POINT 32580	32581	32582	32583	...	32760	32761

①

DATA POINT 32399	32400	32401	32402	...	32578	32579

⑱⑨

DATA POINT 1	2	3	4	...	180	181

```
0001            IMPLICIT INTEGER(A-Z)                                    65
0002            DIMENSION V(27)
0003            DIMENSION A(2600),B(792),C(256)
0004            DIMENSION D(181),E(200)
0005            CALL SETFIL(6,'LP',IERR,'LP')
0006            CALL SETFIL(4,'MT',IERR,'MT',2)
0007            CALL SETFIL(3,'MT9',IERR,'MT',3)
0008            V(01)=12799
0009            V(02)=12593
0010            V(03)=12593
0011            V(04)=12593
0012            V(05)=12849
0013            V(06)=12850
0014            V(07)=12850
0015            V(08)=13106
0016            V(09)=13107
0017            V(10)=12595
0018            V(11)=12336
0019            V(12)=12592
0020            V(13)=12336
0021            V(14)=48
0022            V(15)=13616
0023            V(16)=48
0024            V(17)=12337
0025            V(18)=49
0026            V(19)=13616
0027            V(20)=48
0028            V(21)=12337
0029            V(22)=-21711
0030            V(23)=0
0031            V(24)=0
0032            V(25)=0
0033            V(26)=0
0034            V(27)=0
0035            MC=0
0036            IC=0
0037            CALL WTRAN(3,V,27)
0038            CALL WAIT(3)
0039            DO 805 I=1,38
0040            DO 800 J=1,256
0041      800   C(J)=0
0042            CALL WTRAN(3,C,256)
0043            CALL WAIT(3)
0044      805   CONTINUE
0045     1000   CONTINUE
0046            ICOUNT=1
0047            KTEST=2376+MC
0048            JZ=MC
0049            KK=MC
0050        1   CONTINUE
0051            DO 10 I=1,3
0052            CALL RTRAN(4,B,792)
0053            CALL WAIT(4)
0054            DO 5 K=1,792
0055            JZ=JZ+1
0056        5   A(JZ)=B(K)
0057       10   CONTINUE
0058            JJ=0
0059            DO 150 I1=1,13
```

```
0060             DO 100 J=1,181
0061             JJ=JJ+1
0062             K=182-J
0063       100   D(K)=A(JJ)
0064             DO 105 J=1,39
0065       105   C(J)=0
0066             K=0
0067             DO 110 J=40,220
0068             K=K+1
0069       110   C(J)=D(K)
0070             DO 115 J=221,256
0071       115   C(J)=0
0072             IC=IC+1
0073             IF(IC.EQ.182) GO TO 999
0074             CALL WTRAN(3,C,256)
0075             CALL WAIT(3)
0076             WRITE(6,7000) C
0077      7000   FORMAT(10I6)
0078       150   CONTINUE
0079             KK=KK+23
0080             JZ=KK
0081             DO 200 K1=1,KK
0082             K2=KTEST-(KK-1)-1
0083       200   E(K1)=A(K2+K1)
0084             KTEST=KTEST+23
0085             DO 210 K3=1,2600
0086       210   A(K3)=0
0087             DO 215 K4=1,KK
0088       215   A(K4)=E(K4)
0089             ICOUNT=ICOUNT+1
0090             IF(ICOUNT.EQ.8) GO TO 225
0091             GO TO 1
0092       225   CONTINUE
0093             DO 600 J=1,181
0094             JJ=JJ+1
0095             K=182-J
0096       600   D(K)=A(JJ)
0097             DO 605 J=1,39
0098       605   C(J)=0
0099             K=0
0100             DO 610 J=40,220
0101             K=K+1
0102       610   C(J)=D(K)
0103             DO 615 J=221,256
0104       615   C(J)=0
0105             IC=IC+1
0106             IF(IC.EQ.182) GO TO 999
0107             CALL WTRAN(3,C,256)
0108             CALL WAIT(3)
0109             E(1)=A(2558)
0110             E(2)=A(2559)
0111             E(3)=A(2560)
0112             DO 650 IQ=1,2600
0113       650   A(IQ)=0
0114             MC=3
0115             DO 675 IQ=1,3
0116       675   A(IQ)=E(IQ)
0117             GO TO 1000
0118       999   CONTINUE
0119             DO 815 I=1,37
```

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```
0120          DO 810 J=1,256
0121      810 C(J)=0
0122          CALL WTRAN(3,C,256)
0123          CALL WAIT(3)
0124      815 CONTINUE
0125          CALL SPCL(3,2)
0126          CALL WAIT(3)
0127          CALL SPCL(3,2)
0128          CALL WAIT(3)
0129          WRITE(6,2000)
0130     2000 FORMAT(1X,'COMPLETE')
0131          CALL EXIT
0132          END

$EOD


     ROUTINES CALLED:
     SETFIL, WTRAN , WAIT  , RTRAN , SPCL  , EXIT

     OPTIONS =/ON,/OP:2

     BLOCK        LENGTH
     MAIN.   5104   (023740)*

     **COMPILER =7=-- CORE**
        PHASE      USED  FREE
     DECLARATIVES 00622 13934
     EXECUTABLES  01503 13053
     ASSEMBLY     01617 17628
```